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(NASA-CR-161953) BREADBOARD STELLAR TRACKER SYSTEM TEST REPORT, VOLUME 1 Final Report (Ball Aerospace Systems Div., Boulder) 192 p HC A09/MF A01 CSCL 14B

N82-16170

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BREADBOARD STELLAR TRACKER SYSTEM
TEST REPORT

TR81-04 August 1, 1981

VOLUME I

Prepared for
George C. Marshall Space Flight Center
NASA
Contract No. NAS8-34263

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.1 BACKGROUND

The objective of this test program was to evaluate the performance of a star tracker which uses a G.E. ST-256 CID as the focal plane detector. The CID is an array of 256 x 256 pixels which are 20 x 20µm in dimension. The tracker used for test was a breadboard tracker system developed by BASD. Unique acquisition and tracking algorithms are employed to enhance performance. A pattern recognition process is used to test for proper image spread function and to avoid false acquisition on noise. A very linear, high gain, interpixel transfer function is derived for interpolating star position.

The Nikon F-2.8 lens used in the tracker has an EFL of 100 mm. The tracker has an FOV of 2.93 degrees resulting in a pixel angular subtense of 41.253 arc sec in each axis. It should be noted that the CID used in this tracker is a research device procured from GE. The device was furnished with peripheral circuits packaged in breadboard fashion. It was essentially the first of its kind and had not been tested beyond a level necessary to insure it was operational when received by BASD. The tracker's projected performance was based entirely on data taken from a previous 128 x 128 CID fabricated and tested by G.E.

The test program of this report, conducted with funds provided under MSFC contract No. NAS8-34263, was designed to evaluate only the tracker system performance. No detailed CID characterization tests were conducted under this program.

1.2 APPROACH AND EXTENT OF TEST

Appendix A is a copy of the test procedure (BASD No. 2332-101) used for the program. This procedure presented a star to the tracker in a circular pattern of positions; the pattern was formed by projecting a simulated star through a rotatable deviation wedge.

Two diameters were used for the circle, a small diameter of approximately 4 pixels and a large diameter of approximately 14.5 pixels.

Five small circle locations were tested with the CID temperatures at 0°C, 10°C and 20°C and with star magnitudes of approximately 1.0, 2.8 and 6.0 Mv. Thus, nine small circles of data were taken at each of the five locations. Each data circle consists of 60 data points taken at approximately 6 degree intervals of wedge rotation. Each data point represents the mean of 5 readings.

Each small data circle sampled approximately 65 different pixels and used 16 different interpixel transfer function cycles in each axis.

The large circles were taken only at 0°C and 2.8 Mv. The number of data points and readings were the same as those used for the small circle readings. Each large circle sampled approximately 720 different pixels and uses 30 different transfer function cycles in each axis.

Table 1-1 shows the CID extent for pointing accuracy.

The pointing accuracy test was automated to take 60 data points for a circle in less than 10 minutes. The raw pixel data for the track cycle was stored on floppy discs. The computer then determined position and error for the data relative to a best fit circle. All data was normalized to the pixel dimension of 20μm.

Further tests determined readout noise, Noise Equivalent Displacement (NED) during track, and spatial noise during acquisition by taking related data and reducing it. The standard deviation for a number of readings at a fixed position was used to determine readout noise and NED. Coarse and fine maps were developed using the tracker acquisition mode. These maps were examined to determine the maximum spatial noise as it applies to the coarse and fine acquisition modes.

Table 1-1

EXTENT OF ACCURACY DATA

	Small Circles	Large Circles	Total
No. of locations for circle	5	5	10
No. of circles of data	45	5	50
No. of different pixels used	325	3,600	3,925
No. of different transfer function cycles	160	300	460
No. of position measurements	2,700	300	3,000
No. of readings taken	13,500	1,500	15,000

Extensive exploratory tests and analyses identified potential sources of error and methods of improving performance.

The test results are summarized in paragraph 1.3 below. Further detail on the test approach and results are provided in Sections 2, 3 and 4 of this report. Volume II contains a complete set of the data that was taken.

1.3 SUMMARY OF TEST RESULTS

All position, dimensional and accuracy data has been normalized to the 20µ pixel dimension and can be related to angle by the scale factor of 41.253 arc secs per pixel.

Accuracy data related to an arbitrary reference on the CID is all inclusive. No attempt has been made to separate error sources such as instability, test equipment, quantization, image uncertainty, etc.

Tracking data was taken using an LED source with a center wavelength of 656µm and the tracker lens set at F-2.8.

1.3.1 Interpixel Transfer Function Linearity

The linearity of the interpixel transfer function was evaluated over several cycles and results indicated that there is less than ± 0.005 pixels-RMS deviation from a straight line. This performance is equivalent to that predicted by BASD's analyses.

1.3.2 Interpixel Signal Scale Factor

The scale factor (Signal vs. Displacement) for pixel-to-pixel transfer is approximately 1.7 times the total image signal per pixel displacement. The theoretical limit is 2.0. The expected scale factor was approximately 1.9 times the image signal per pixel displacement.

The scale factor is inversely proportional to image diameter. For this sytem the minimum "apparent image diameter" appears to be defined by the pixel-to-pixel cross talk in the CID.

1.3.3 Readout noise

A random readout noise of 278 e^- per pixel was observed for the CID focal plane and is consistent with G.E.'s prediction and is reduced to approximately 35e^- per update by the multiple read Non Destructive Read Out (NDRO) process developed by G.E.

If the system bandwidth is equal to the pixel data rate of 5000 Hz, the read-out noise constant is 3.93 e^- per $Hz^{1/2}$

1.3.4 Spatial Noise For Coarse Acquisition

The double read subtraction process for coarse acquisition takes approximately 4 seconds miminum and results in an integration time of 2 seconds which can be increased by adding integration time between reads. A maximum spatial noise of $10^5 e^-$ was observed.

BASD's design is based on a minimum star signal of 3.3 x $10^4 e^-$ per second. By adding two seconds integration to the acquisition time this signal should rise above the noise level and result in an acquisition time of 6 seconds for a minimum star signal level.

1.3.5 Spatial Noise For Fine Acquisition

Using an integration time of 0.5 second fine acquisition maps revealed a worst case spatial noise of $10^4 e^-$. This is below the minimum star signal level and fine acquisition can take place in less than 1 second without false attempts.

1.3.6 Acquisition Performance

The acquisition modes were not optimized beyond the point required to acquire stars for accuracy testing. Extensive testing in this area was considered to be inefficient at this time; however, acquisition was readily achieved for the 1 Mv to 7 Mv star range used in this test program under the basic conditions of paragraphs 1.3.4 and 1.3.5. A significant number of false acquisition attempts were observed for stars dimmer than 6 Mv, especially at the 20°C CID operating temperature.

The pattern recognition process effectively rejected acquisition on spatial noise when thresholds were below noise level.

1.3.7 Position Accuracy Performance

For stars brighter than 3 Mv the accuracy performance was ± 0.0178 pixels RMS. There was no significant variation in accuracy using CID temperatures ranging from 0°C to 20°C. The errors for large circles were slightly larger than for small circles, a degradation attributed to changing focus resulting from nonorthogonality of the CID plane to optical axis alignment.

The accuracy for the 6 Mv star magnitude did vary with CID temperature changes. The results from all the 6 Mv star data are as follows:

CID TEMPERATURE	ACCURACY
0°C	± 0.0282 RMS
10°C	± 0.0266 RMS
20°C	± 0.0465 RMS

These results are inconsistent with BASD's previous analyses which showed tracker accuracy would be limited by pixel-to-pixel variations in dark current. Therefore, all data should show degraded accuracy with increasing CID temperatures. The errors for the 6 Mv star magnitude do change with temperature but do not follow the predicted trend and are higher then expected.

1.3.8 Sources Of Error

The analysis indicated that accuracies of ±.005 pixels to ±.015 pixels RMS should be achievable for CID temperatures of 0°C to 20°C respectively.

Review of data for stars brighter than 3 Mv does not reveal a trend of degraded accuracy with increased CID dark current. The transfer function linearity error (Subsection 1.3.1) meets the criteria for the projected accuracy.

Another error source, not previously identified, was suspected and an extensive evaluation and exploratory test program was conducted by BASD to identify the error sources.

The conclusion is that the accuracy for bright stars could be limited by present mechanization problems rather than by uncertainties in the CID (except for bad areas in the CID). A solution to this problem has been defined but not yet implemented and tested. The problem and solution are briefly summarized below.

- The CID design provides access to a 4 x 4 block of pixels with one address.
- BASD's mechanization requires sampling a dark pixel for use as a reference for common mode noise rejection.
- In order to conserve time, the dark pixel is sampled from the same 4 x 4 block used to sample the star signal pixels. This results in sampling "dark" pixels adjacent to the pixels on which a star is imaged.
- Sufficient pixel-to-pixel cross talk exists in the CID; therefore, a pixel adjacent to the star image also receives star signal.

- The cross talk into the dark reference pixel results in biasing the transfer function for varying star positions which could result in position bias errors.

The problem can be minimized by advancing the data block when taking dark data, and thereby assuring that the dark pixel is never sampled adjacent to the signal pixels. Although this takes more time, it is estimated that the resultant increase in NED will be less than 10%.

Other potential sources of error that have not been investigated are:

- Pixel-to-pixel response variations
- Pixel point spread response function and variations
- Effects of the injection pulse
- Test equipment errors (non-flat wedges)
- CID misalignment (non-orthogonal alignment)
- Image distortion
- Chromatic effects of Cid and lens

1.3.9 Noise Equivalent Displacement (NED)

The NED was tested using a 5.9 Mv star with varying update time. Results are tabulated below in Table 1-2.

The NED performance closely follows the predicted pattern in that for short update times it is dominated by readout noise, and for longer update times it is dominated by signal and dark current shot noise.

Taole 1-2

NED VS. UPDATE TIME (Tu)

Mv = +5.9

Tu (seconds)	NED (RMS Pixels) x	y
.080	.0695	.0431
.150	.0215	.0208
.250	.0086	.0083
.500	.0043	.0037
.800	.0028	.0025
1.300	.0032	.0029

1.3.10 Tracking Rate

Initial attempts to conduct the accuracy test resulted in frequent loss of track while moving the wedge, and consequently the star image to a new position. Due to this problem and an excessive long acquisition time for dim stars, star pattern recognition logic and a portion of the adaptive rate control were implemented. Thereafter, few loss of track events were experienced, and when they were, the star was reacquired with little time lost in taking a circle of data.

The adaptive rate control allows for tracking without degradation in accuracy to rates of 0.5 pixels per update. There is an associated lag in position data and a slight decrease in the transfer function slope; however, both are predictable.

The tracker should maintain track to rates equivalent to 1 pixel per update.

The test was not set-up for precision measurements at high rates and the tracking accuracy could not be verified; but an open loop test was conducted to verify track was maintained at 1 pixel per update. This was accomplished by driving the star in a large circle pattern at maximum wedge rate and estimating the pixel rate of the image. The update time was increased for an

equivalent rate of 1 pixel per update. The rate used was approximately .5 pixels/second.

1.3.11 General Performance of the ST-256 CID

Detailed characterization tests for the CID were not part of this program; however in the coarse of conducting the tracker test some general observations were made.

- CID environments and operating time

  The ST-256 was exposed to uncontrolled handling and environments typical of most R & D programs. During the development and troubleshooting process the focal plane was removed and reinstalled in the optical head many times. The CID sealed glass coverplate was inadvertently cracked during a microscope inspection early in 1981 and was subsequently removed. A dry N_2 purge was added to provide an inert environment for the exposed detector. Unobserved loss of the N_2 supply during a 0°C test resulted in frost formation on the CID chip.

  The unit was transported between facilities at BASD. It was shipped to Washington D.C., May 1981 and subsequently subjected to low level radiation to evaluate noise susceptability.

  BASD has operated the CID on an almost continual basis since its receipt in July 1980. Estimating its on-time at 80%, approximately 1700 hours have accumulated on this device without noticeable performance degradation.

- CID Noise

  The star tracker readout noise is slightly less than the 300e$^-$ predicted by G.E.

Spatial noise was not evaluated, but, it appears to approximate G.E.'s predictions. Refinements to the acquisition and track algorithms will provide more insight into average spatial noise limitations.

Some abnormal local dark current generation was observed as was expected. However, the frequency of occurrence should be low relative to the total CID area.

This CID appears to have several high current areas or "hot spots". These hot spots were noted in false acquisition attempts and, in some cases, in false tracking when thresholds were set low. No quantitative measurements were made except for the area where accuracy tests may have been performed.

This particular device also exhibits a large electrically coupled noise pulse immediately following injection. The anomally was observed by G.E. prior to delivery and was attributed to an error in the chip mask. The amplitude of this pulse can be reduced by a mask change. Common mode noise rejection in the tracker design minimized the effect on tracker performance. The most noticeable effect was a reduction in the usable dynamic range of the A/D converter. The same problem relates to the fixed pattern noise evident in the CID.

- CID dark current

The CID dark current was continually monitored in accordance with the procedures of Appendix A. The measurement made using the dark reference pixels errs somewhat since the pixels contain some signal (subsection 1.3.8).

The measured mean dark current is approximately 10^4e^-, $2.4 \times 10^4e^-$ and $5 \times 10^4e^-$ per pixel-second at 0°C, 10°C and 20°C respectively. These levels were obtained from dim star tracking and are consistent with the expected results.

- CID Responsivity

  Star magnitude is determined by using the track signal pixels and computed in accordance with Appendix A procedures. The tracker Mv computation is made using the spectral response curves obtained from a G.E. report on the 128 x 128 CID. A test determined that the computed Mv magnitude and that measured with a photometer agree within ±.5 Mv for stars in the range of 1.0 Mv to 6.0 Mv. This is close enougn to lend credibility to the predicted CID response.

1.4 CONCLUSION

The trackers performed with an accuracy of approximately ± .02 pixels RMS at 0°C. The tracker's scaling is 41.253 arc sec per pixel resulting in an accuracy of ± 0.82 arc sec over the 2.93 degree FOV.

The accuracy of ± .02 pixels, or 1 part in 12,800 for the total FOV, is impressive when compared with sensors using past technologies. However, it does not meet the degree of accuracy BASD feels the tracker can ultimately achieve.

From the results of this test and previous studies, it is concluded that the CID star tracker remains a primary candidate for continued development and performance-evaluation. A potential error resulting from the existing mechanization as discussed in subsection 1.3.8 can be corrected. Other potential sources of error remain to be investigated. Since our projected linearity (better than ±0.005 pixel) for the interpixel transfer function was verified and since accuracy is not yet limited, at least for brighter stars, by the CID dark current, it appears that further improvements can and should be made.

1.5 RECOMMENDATIONS FOR FUTURE WORK

A variety of areas require further study, development and evaluation. The extent of effort associated with each depends on the objectives to be accomplished. The effort suggested below is directed at defining the CID tracker capabilities and shortcomings in order to eliminate technical risk from future

flight development programs. The recommended future efforts related to both the CID and the tracker system design are summarized below.

1.5.1 Proof of System Concepts

BASD has completed extensive analyses and studies related to:

- Acquisition
- Automatic Gain Control (AGC)
- Adaptive Rate Control
- Multiple Star Tracking
- Tracking Accuracy

The completion of the following recommendations will result in a higher degree of confidence relative to the expected performance in each area.

-- Improved Accuracy

A potential systematic source of error has been identified in this test program and can be eliminated with a software change. It is recommended that the change be implemented in the existing equipment and that the test be repeated to verify maximum tracking accuracy for a tracker without compensation or calibration. Other potential sources of error should also be investigated under this task.

-- Improved Acquisition and Rate Tracking

A portion of the acquisition logic and adaptive rate control were mechanized to complete this test program. Additional functions must be added to optimize performance in both areas. It is recommended that these functions be added and evaluated in the existing system.

-- Multiple Star Tracking and AGC

Thresholds and gains can be readily selected for proper acquisition and track of a single star. However, for multiple star tracking the signal from the related sources may be several orders of magnitude apart. To acquire, select, and track these sources in a reasonable amount of time, it is necessary to automate the acquisition ranging and gain of the track loop. BASD has studied this problem and formulated various concepts to achieve the desired performance. It is recommended that these concepts be refined and implemented in the existing hardware for evaluation.

1.5.2 CID Study and Evaluation

Recommendations for study in the CID performance and the readout process applicable to tracker acquisition and track modes are as follows.

-- CID Characteristics and Specification

Several CID's should be fully characterized and evaluated in order to establish confidence in their performance in future trackers. A specification for the CID performance parameters should be written reflecting the results of this evaluation program.

-- CID Design and Readout Approach

The CID design and the readout approach should be thoroughly reviewed with the following objectives:

- Elimination of injection pulse
- Reduced pattern noise
- Reduced readout noise
- Improved data and processing rates
- System Simplification

Any significant improvements should be breadboarded and tested.

-- Mechanical/Thermal Design

General packaging concepts should be studied in order to establish a stable design which can withstand launch and space environments. The design should provide adequate cooling for the detector and a means for heat transfer of cooler power. A mechanical model should be fabricated and environmentally tested to ensure these requirements are met.

1.5.3 General Study Items

- Optics

An analysis of the full spectrum of CID spectral sensitivity for typical lens performance and CID point response should be conducted to relate tracker performance versus star color. Whenever possible, cromatic verification tests should be conducted using breadboard hardware.

- Parts Status and Power Estimates

A detailed study should be conducted on parts for use in a flight unit and should include plans to qualify or change nonstandard parts. A detailed power estimate should be made based on a typical design for flight application using reasonably acceptable parts.

Section 2
TEST APPROACH AND EQUIPMENT

2.1 GENERAL APPROACH

A compound reflective/refractive system which projects a light source to infinity was used for the star simulation. The star light was projected through a motorized, compound, rotatable deviation wedge assembly. As the wedges are rotated in the drive assembly, the star appears to move in a circular path. This circular locus of the star image is the positional input to the star tracker optical assembly for position accuracy tests.

The star tracker optics consist of the ST-256 CID detector mounted at the focal plane of a Nikon F-2.8 camera lens. A Cromemco Z-80 microprocessor development system is interfaced to the star tracker optics which performs the acquisition and track logic functions. The star simulator, wedge drive assembly and star tracker optics are mounted on an isolated test surface plate to provide maximum mechanical stability.

A block diagram of the test setup is shown in Figure 2-1

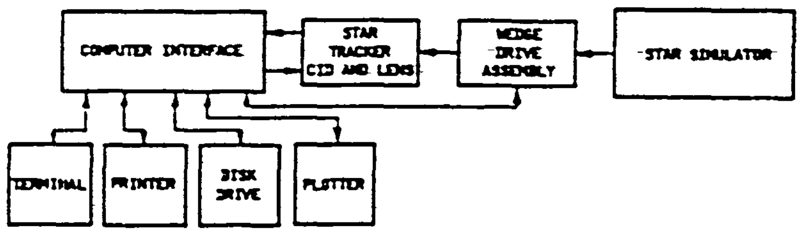

Figure 2-1 Block Diagram of Overall Hardware System

2.2 STAR SIMULATOR

The star simulator projects a light source from an LED to infinity. Monochromatic light was used to eliminate optical problems associated with ordinary white light when using a commercial lens. The LED output is a green light of approximately 656nλ wavelength.

The intensity of the simulated star was varied by an external power supply. Three star intensities used gave a range of about five star magnitudes. The EFL of the simulator is 61 cm. An aperture diameter of 0.051 mm was used in front of the LED which resulted in an angular subtense of 17.25 arc sec. (less than half the pixel dimension). A photograph of the star simulator is shown in Figure 2-2.

2.3 DEVIATION WEDGE DRIVE

The wedge drive assembly is located in the optical path between the star simulator and star tracker optics. The assembly contains two independent sets of counter rotating gears. Either set may be independently driven by a D.C. motor coupled to the gears. Four deviation wedges with adaptors are provided with the assembly. The deviation angle of each is approximately 12 arc min. Counter rotating the wedges produces a linear deviation of the star light as a function of wedge rotation. A single rotating wedge simulates circular motion of the star.

Figure 2-3 illustrates the concept.

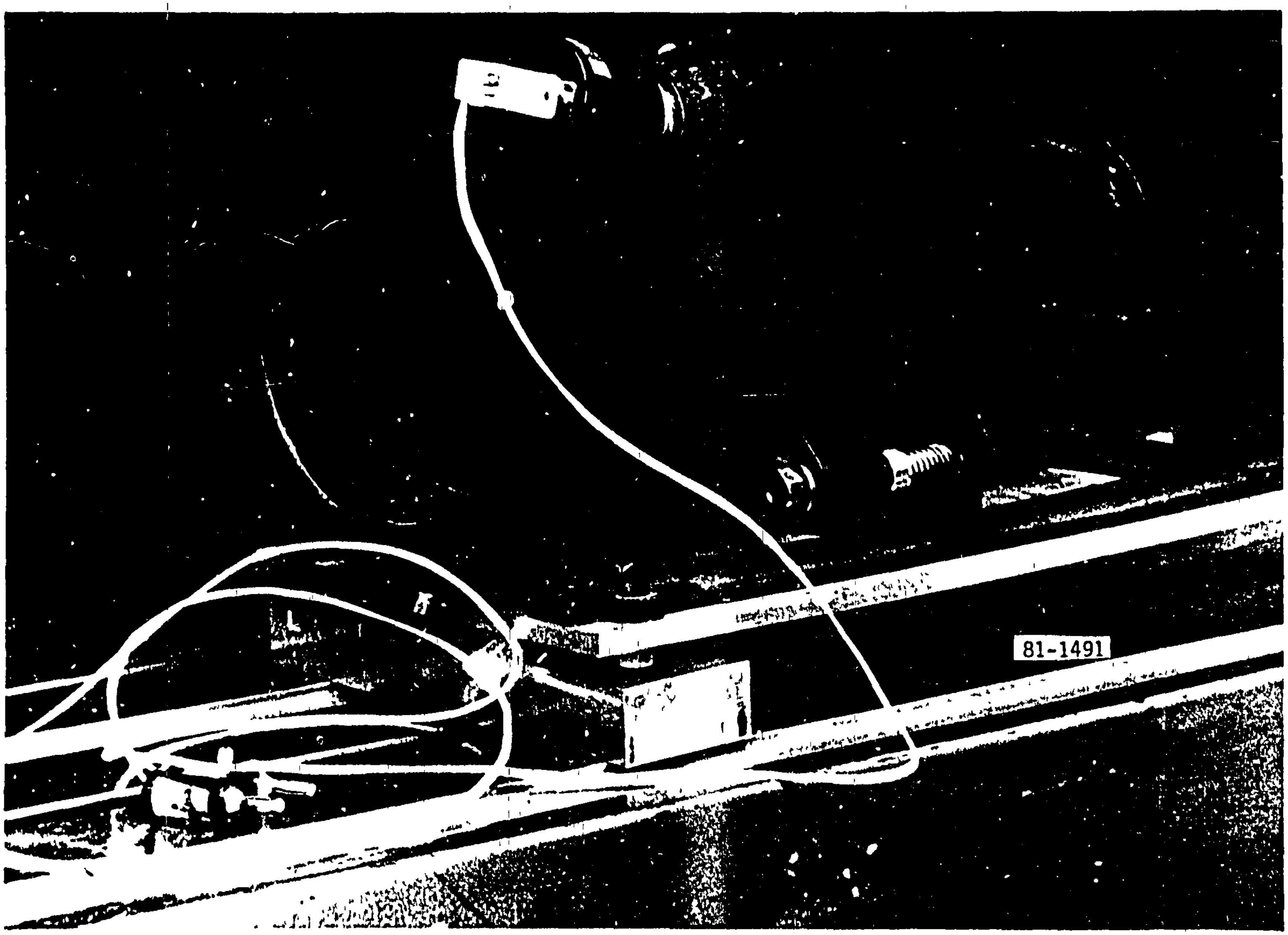

Figure 2-2 Star Simulator

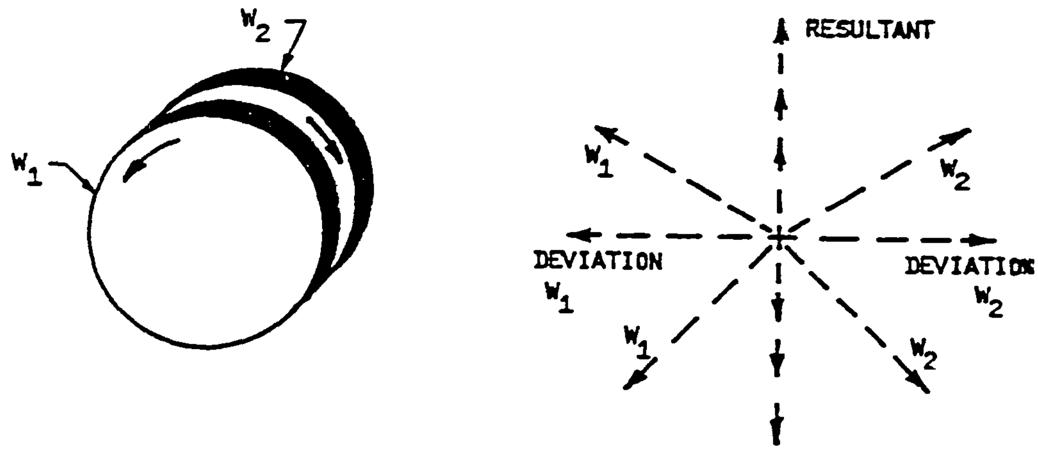

Figure 2-3a. Two Counter Rotating Wedges Produce Linear Motion

Figure 2-3b. Single Rotating Wedge Produces a Circular Motion

When two wedges are attached to one gear, indexing their deviation vectors produces a desired resultant deviation. Both wedges rotating together result in a circular motion with an adjustable angular diameter of 0 to 24 arc min.

A scribe line on each wedge indicates the direction light will be deviated. Each wedge housing has 132 teeth, on its periphery at intervals of 2.727 degrees. These teeth, along with the wedge scribe, allow for course indexing of wedge pairs to achieve a desired resultant deviation. A lock for the gears farthest from the motor is provided to select the set which is driven. The two sets are coupled through planetary friction drive gears.

A one percent continuous turn servo potentiometer is coupled to one gear of either counter rotating set. The coupling gear ratio is 1:5 so that with one complete gear rotation the potentiometer rotates through five cycles. Each pot rotation corresponds to 72 degrees of gear and associated wedge rotation.

The control box which drives the wedges can be set to either incremental steps of wedge rotation (manual or computer initiated) or free continuous run (set manually). The speed of the rotation is manually variable from zero to a maximum. The wedge rate control is open loop in either case. Figure 2-4 is a photograph of the wedge drive assembly.

2.4 STAR TRACKER

The CID is a 256 x 256 pixel detector array with a pixel size of 20 x 20 µm. The array is designed for parallel row readout and includes integral shift registers. The CID signals are processed using double read nondestructive readout (NDRO). The process reduces fixed pattern and readout noise.

The effective focal length of the Nikon lens is 100 mm giving each pixel an angular subtense of approximately 41.253 arc sec. The array, therefore, provides a square field of view of approximately 2.933 degrees on an edge. The CID imager is mounted on a board which contains the hardware circuitry for

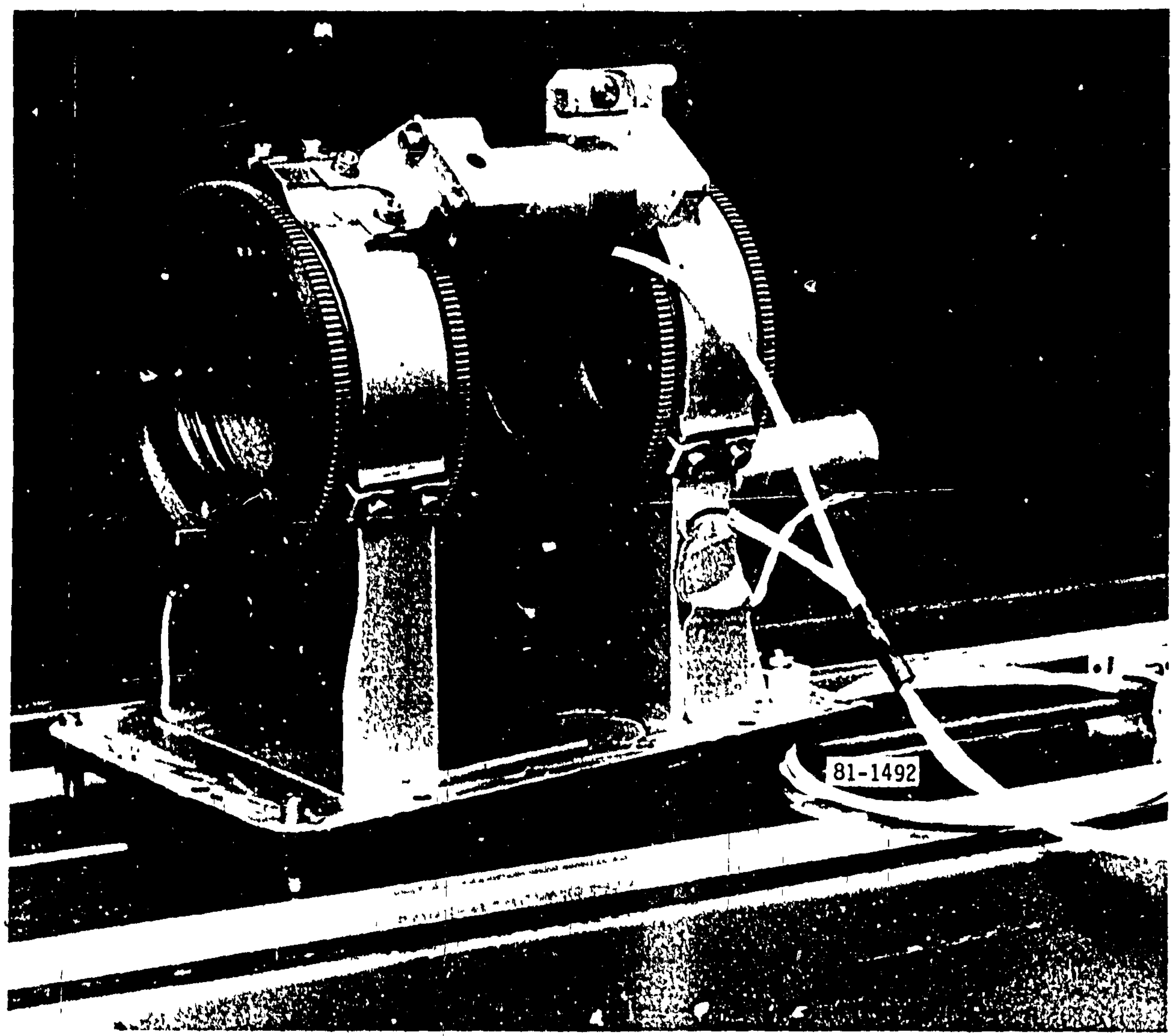

Figure 2-4 Wedge Drive Assembly

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reading out the array. The board also has the CID cooler circuit on it. The analog CID signals are directly digitized by an A/D converter to usable form for the microprocessor.

Figure 2-5 is a photograph of the CID and circuit board. Figure 2-6 is a photograph of the complete tracker optics.

2.5 COMPUTER HARDWARE

The CID tracker data is acquired and processed in software. Complete control and analysis of this system is performed by the Z-80 microprocessor through a Cromemco development system. The interface box consists of several computer hardware cards with interfaces to the CID, terminal, line printer, and plotter. The terminal displays real time data as the star tracker acquires and tracks stars. Data is stored on floppy disks and then printed out by the line printer. The plotter then plots the acquired data.

Figures 2-7 and 2-8 are photographs of the computer hardware and peripheral test equipment.

2.6 GENERAL TEST CONDITIONS

During tests, the room lights were off and other light sources were minimized. Operation was conducted at ambient room temperature and a hood was placed over the tracker, wedge assembly, and simulator to provide a more stable temperature environment by minimizing convection currents. The CID had a constant N_2 purge of about 20 lb. while the system was running and about 5 lb. when the tracker was off. The data was taken at three different CID temperatures. Temperature variation is accomplished through use of the T-E cooler upon which the CID is mounted.

Figure 2-5. CID Board and Lens

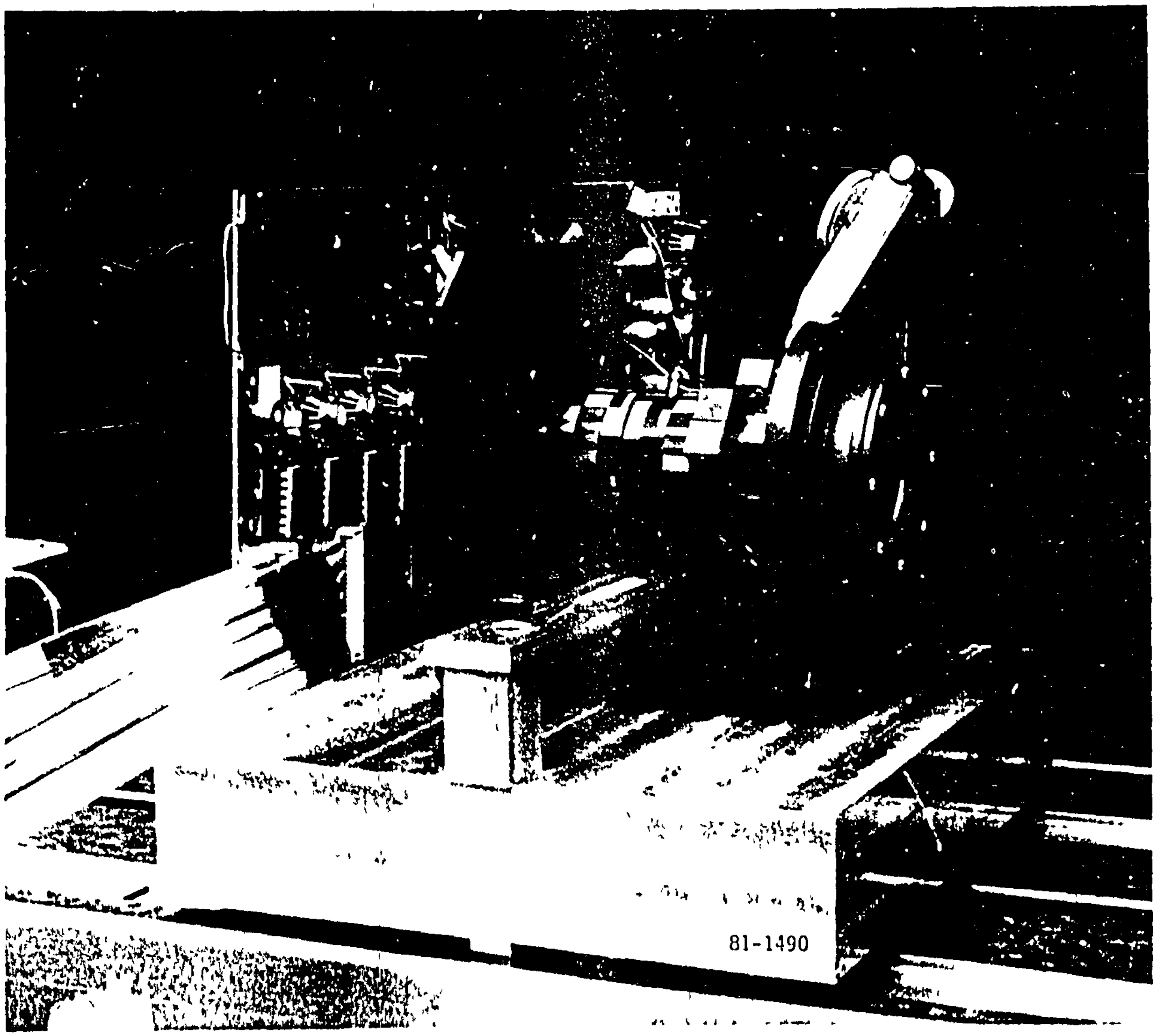

Figure 2-5 CID Board and Lens

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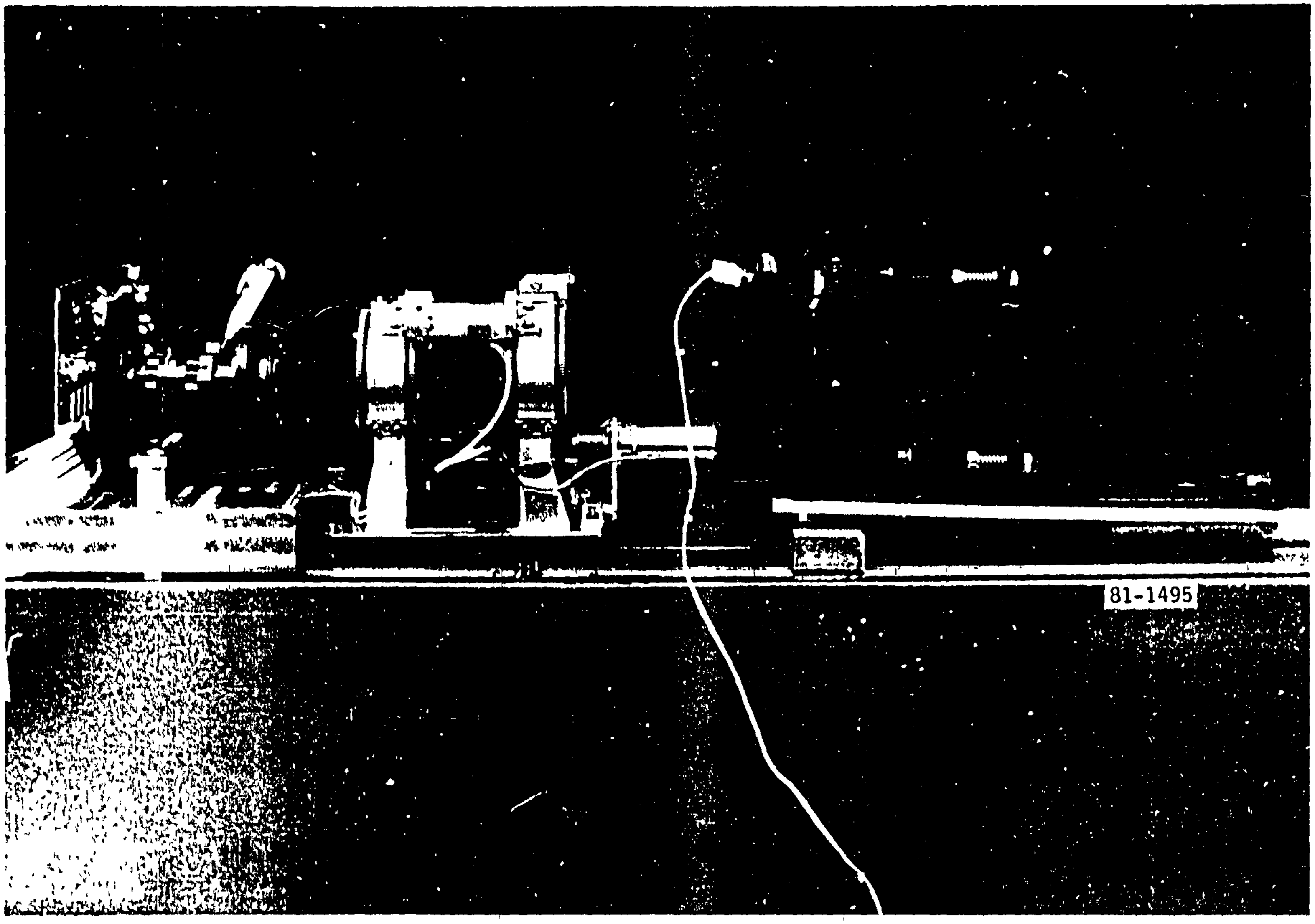

Figure 2-6 Complete Tracker Optics

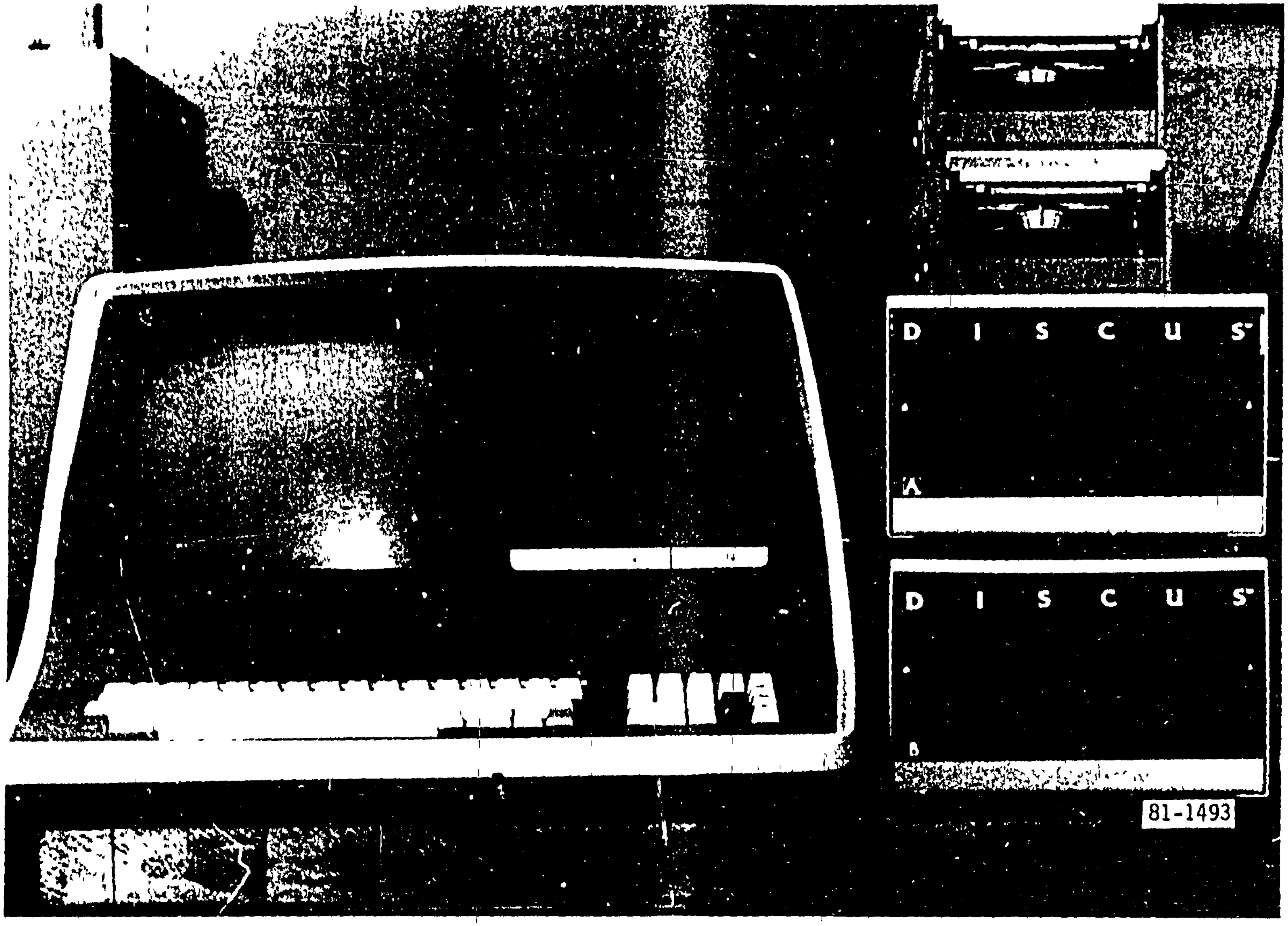

Figure 2-7 Complete Hardware

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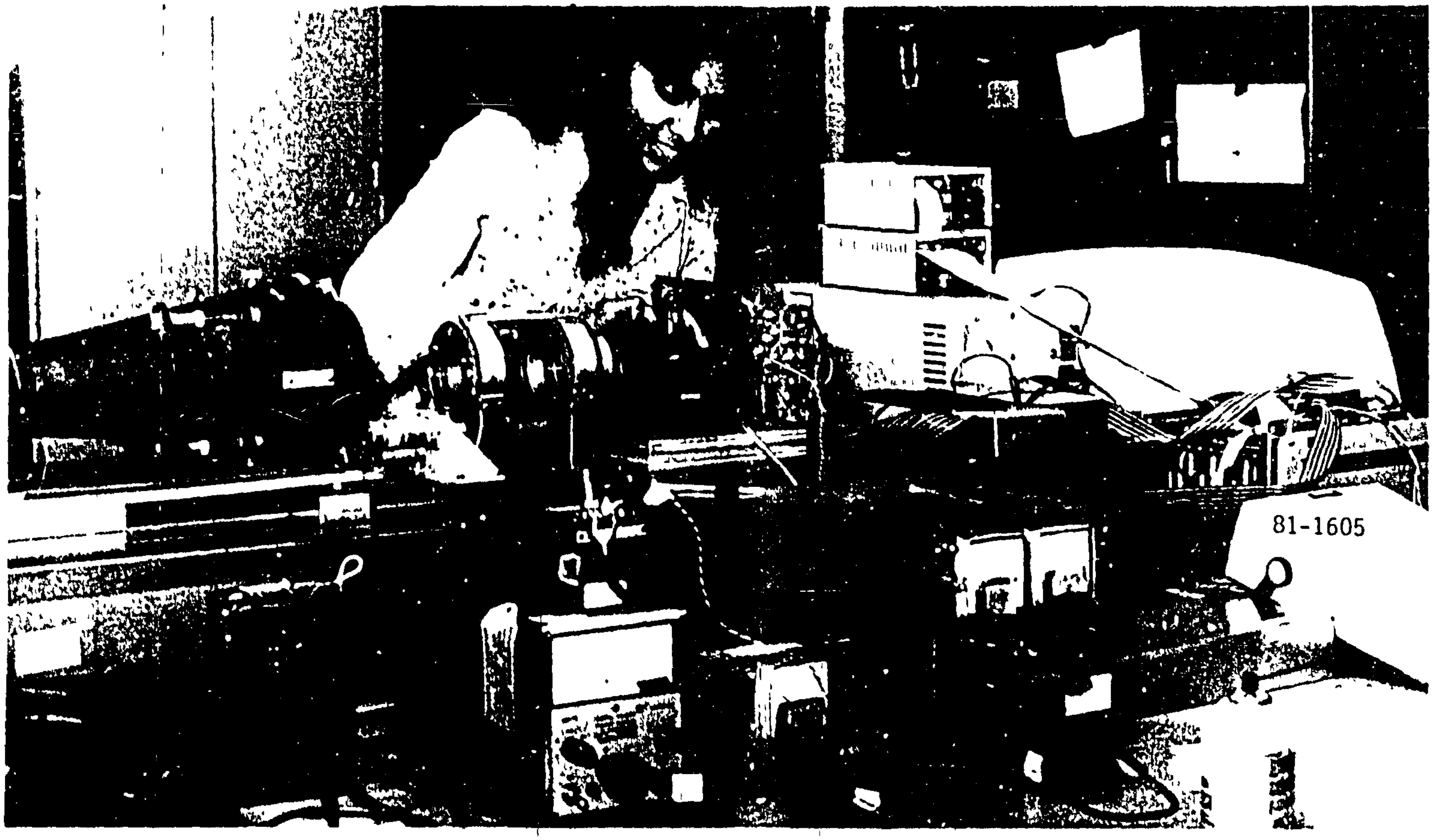

Figure 2-8 Peripheral Test Equipment

Section 3
TEST RESULTS

3.1 NOISE TESTS

3.1.1 General Considerations

Noise is represented by basic random or spontaneous fluctuations resulting from the physics of the devices and material which comprise the electrical system. The performance of the CID tracker depends upon the noise generated within the system; which is categorized as temporal noise (random noise) and pattern noise (spatial noise) are of particular concern.

3.1.2 Temporal Noise

Temporal noise is a totally random signal and the two major sources are Johnson noise and shot noise. Johnson noise is the dominant temporal noise source at high rates and is proportional to the square root of the bandwidth. Shot noise is proportional to the square root of the signal, and in this case, the signal can be light or dark signal/current. Shot noise typically becomes dominant at high temperatures or long update times.

3.1.3 Pattern Noise

The two types of pattern noise which are of concern are "fixed" pattern noise which repeats with each reading and "variable" pattern noise which is not repeatable. The latter may vary according to time, temperature, and signal level.

The major sources of fixed pattern noise in CID image sensors are transistor switching interference, array photolithographic variations and bias charge variations. The variable types of pattern noise result from spatial variations in dark current and responsivity.

The device used in this test program had another noise source resulting from an error in the CID mask design. This noise occurred as a pulse coupled into the signal line immediately after injection and had a long decay time and gave the CID the appearance of having a shaded spatial time dependent response. This problem can be eliminated or minimized in future devices by a correction to the mask design.

3.1.4 Noise Suppression Techniques

The temporal noise is reduced by repeated CID nondestructive readings or updates. This process effectively reduces the Johnson noise by a factor equivalent to the square root of the number of readings taken and is used in both the acquisition and track modes of operation.

Fixed electrical pattern noise is minimized by the double read, nondestructive method of readout. Two consecutive sets of read samples are differenced to cancel the repetitive spatial noise interference, ideally leaving the signal behind.

Dark current pattern noise can be reduced by cooling the CID to minimize the mean dark current. The variations (spatial noise) in dark current and responsivity are inherently low in the CID. Further reduction is accomplished by averaging the effects over several pixels in the readout process.

The effect of the injection pulse was minimized using common mode rejection techniques. A pattern recognition process implemented in the tracker results in overriding acquisition on noise. The noise primarily effects the time for acquisition and tracking accuracy.

3.1.5 Noise Tests

Tests were conducted to define the temporal and pattern noise evident in the CID tracker.

3.1.5.1 Temporal Noise Data

The temporal noise test was conducted on a block of 16 pixels. 128 nondestructive readings (NDRO's) were taken for each pixel. The second 64 readings were subtracted from the first 64 to eliminate fixed pattern noise. This process was repeated a hundred times for each pixel in the 4 x 4 pixel block. Thus, the (spatial) fixed pattern noise is minimized and random or temporal noise is left. The test was repeated at 0°C and 10°C. The mean and standard deviation for the sets of a hundred readings are shown in Table 3-1 and 3-2. The mean of the readings decreases in value with time as they are read from pixel #1 to pixel #16 because of the injection pulse.

The average standard deviation at 10°C is 17.59 bits. The scale factor is 179.5e^- per bit, so that the temporal noise for 128 readings is 3157.4e^- RMS. The average standard deviation for the 0° data is 3134e^- RMS. Taking the average of the 10° and 0° data, there are 3146e^- RMS for the 128 readings. Since the noise increases as the square root of the number of readings, the noise due to one reading is: $\frac{3146}{\sqrt{128}}$ or $278 \frac{e^-}{\text{readout}}$.

Table 3-1

TEMPORAL DATA FOR 16 PIXELS AT 0°C

Pixel #	Average of 100 Readings $\bar{X}$ (of Signal)	S (Standard Deviation)
1	582.7475	20.0954
2	584.4343	25.2458
3	588.6263	16.3386
4	594.3939	20.6900
5	185.6162	14.0391
6	185.7980	16.4248
7	187.8283	16.5493
8	183.3131	14.5059
9	117.4242	16.4112
10	120.8485	18.4515
11	114.7172	18.6449
12	123.1010	16.2195
13	84.3939	16.7087
14	77.6465	16.3715
15	83.9091	17.1228
16	85.0404	15.2569

Table 3-2

TEMPORAL DATA FOR 16 PIXELS AT 10°C

Pixel #	Average of 100 Readings X (of Signal)	S (Standard Deviation)
1	700.22	17.3523
2	713.06	16.8612
3	697.1	16.0407
4	709.05	17.2060
5	289.38	16.4984
6	302.71	22.4429
7	286.05	18.0903
8	289.18	18.3361
9	214.19	16.7680
10	223.02	18.3809
11	220.60	16.8810
12	222.18	16.7244
13	190.20	15.6870
14	189.61	16.5015
15	197.51	22.1088
16	189.75	15.4111

The noise constant normalized to frequency is: $kn = \frac{278}{\sqrt{5000}}$

$$kn = 3.93e^{-}/\sqrt{Hz}$$

This assumes the bandwidth is equivalent to our sample rate of 5000 Hz.

3.1.5.2 Pattern Noise Data

Volume II of this report, (Section 1.1) of the test data contains coarse and fine maps. Data is presented in hexadecimal units. Each reading on the coarse map is the sum of a block of 4 x 4 pixels. Each reading on the fine map is that of a single pixel. The scaling for these maps is $179.5e^{-}$/bit. The magnitude of the readings is the combined dark current and system noise. The effect of the injection pulse is evident on the coarse map. A graph showing the magnitude of the coarse map reading against time is plotted in Figure 3-1, which shows the effect of the injection pulse on the data. The corresponding data is presented in Table 3-3.

The parameter of significance in the coarse and fine maps is the difference in signal for adjacent readings. By comparing adjacent readings star acquisition is determined. Some significant observations are summarized in Table 3-4.

3.1.6 Conclusions For Noise Test

The observed random readout noise was slightly less than the $300e^{-}$/sample reported by G.E. The pattern noise had not been previously tested for the method implemented in this tracker.

Table 3-3
COARSE MAP READINGS

Set #	Block #	t(msec)	Pulse (e^-) $\times 10^5$	Set #	Block #	t(msec)	Pulse (e^-) $\times 10^5$
1	1	.41	7.399	4	16	85.66	2.870
	2	.82	6.361		32	92.22	2.949
	3	1.23	6.254		48	98.78	3.086
	4	1.65	6.277		64	105.34	2.601
	5	2.06	6.256		16	111.9	2.710
	6	2.47	6.223		32	118.5	2.815
	7	2.88	6.038		48	125.0	2.980
	8	3.30	5.830		64	131.6	2.520
	9	3.71	5.521	6	16	138.2	2.705
	10	4.12	5.441		32	144.7	2.750
	12	4.94	5.302		48	151.3	2.981
	14	5.77	5.179		64	157.8	2.468
	16	6.59	5.119	7	16	164.4	2.675
	20	8.24	5.272		32	170.9	2.707
	24	9.89	5.338		48	177.5	2.985
	28	11.54	5.369		64	184.0	2.430
	32	13.18	5.087	8	16	190.6	2.646
	36	14.83	4.886		32	197.2	2.646
	40	16.31	4.933		48	203.7	3.003
	44	17.80	4.936		64	210.3	2.513
	48	19.70	4.979	9	16	216.8	2.574
	52	21.42	5.001		32	223.4	2.600
	56	23.07	4.805		48	230.0	2.955
	60	24.72	4.681		64	236.5	2.457
	64	26.40	4.141	10	16	243.1	2.671
2	16	32.96	3.542		32	249.6	2.556
	32	39.55	3.606		48	256.2	2.996
	48	46.14	3.570		64	26.8	2.470
	64	52.73	2.933	16	64	422.0	2.357
3	16	59.30	3.060	32	64	844.0	2.395
	32	65.90	3.107	18	64	1265.0	2.233
	48	72.50	3.226	64	64	1687.0	2.276
	64	79.10	2.725				

tr (time to read one block) = .41 msec for this coarse map data

Map scaling = coarse reading (decimal) $\times 179.5 \frac{e^-}{\text{bit}}$

Results shown are the difference of two samples taken approximately 2 seconds apart.

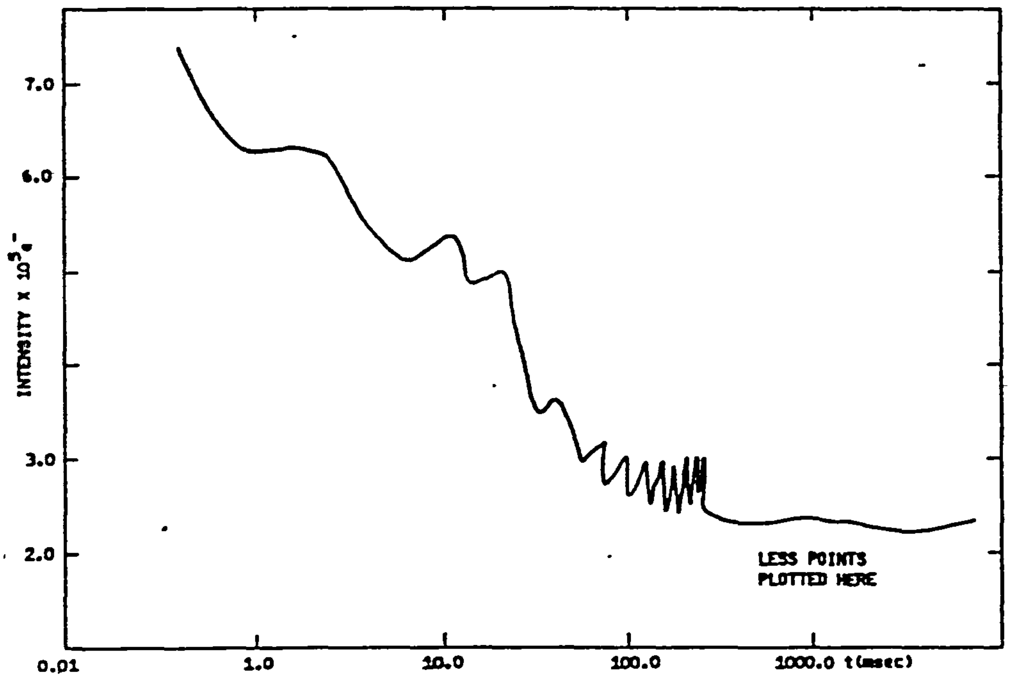

Figure 3-1. Injection Pulse vs. Readout Time

Table 3-4

SIGNAL DATA ON COARSE AND FINE MAPS

Fixed Pattern Noise Data Summary:

MAP		CID TEMP	TR (TOTAL READ TIME)	Ti (TIME BETWEEN READINGS)	SIGNAL	Δ SIGNAL (MAX)
Coarse (Dark)		0°C	3.85 sec	0.125 sec	218272.0e⁻/block	101417.5e⁻
Fine (Dark)						
Location						
20	20	0°C	32 msec	460 msec	4846.5e⁻/pix	3410.0e⁻
15	15	0°C	32 msec	460 msec	5923.5e⁻/pix	5564.0e⁻
10	10	0°C	32 msec	460 msec	6103.0e⁻/pix	7439.0e⁻
20	20	16°C	32 msec	460 msec	18309.0e⁻/pix	5385.0e⁻
15	15	16°C	32 msec	460 msec	19924.0e⁻/pix	5205.5e⁻
10	10	16°C	32 msec	460 msec	20104.0e⁻/pix	9693.0e⁻

The maximum differential signal, Δ signal, between adjacent blocks is what sets the lower acquisition threshold limit. Δ signal should ideally be zero since fixed pattern noise and dark current have been cancelled. The differential signals shown above are the worst occurrence of residual pattern noise, dark current variation and Johnson noise in that location of the CID array for the condition shown above.

The worst case differential signal (or pattern noise) for adjacent blocks in the coarse map at 0°C is approximately 10^5 electrons. Setting the coarse acquisition threshold above this level results in no false acquisition attempts. Our system analysis has considered a signal of approximately $10^5 e^-$/sec for the minimum star. A worst case geometry of the star location relative to a block could reduce this to $3 \times 10^4 e^-$/sec (or 1/3 of the minimum star).

The minimum coarse acquisition time is 4 seconds and yields an effective integration time of 2 seconds. Therefore, approximately 2 seconds of integration time must be added to acquire the minimum star. The total acquisition time would be 6 seconds.

The fine acquisition noise is more favorable. Note that at 16°C, location 10, 10 has a maximum differential signal (noise) of $10^4 e^-$ for approximately a half second integration time. Using the worst case star signal of $3 \times 10^4 e^-/sec$, a fine acquisition time of less than one second should result in no false acquisition attempts. The total acquisition time for both coarse and fine maps for a minimum star should be less than 7 seconds.

3.2 ACQUISITION PERFORMANCE

The acquisition mode for the tracker has not been optimized and no extensive tests were conducted. However, with one set of conditions (fixed thresholds, NDRO's and integration time) the stars over five magnitudes of intensity were readily acquired in less than 10 seconds of time. The pattern recognition concept implemented in the tracker effectively rejected areas of high pattern noise which had previously caused problems in acquiring the dimmer stars. Now stars can be acquired when the star signal is significantly less than the pattern noise.

3.3 POINTING ACCURACY TESTS

3.3.1 <u>General Procedure</u>

The pointing accuracy test was performed in accordance with BASD procedure # 2332-101 (see Appendix A). The test verified the position interpolation algorithm developed by BASD. The design goal was to achieve an error of less than ±1% of a pixel deviation for the output star position from the input position of the star image. Tests were conducted over small areas involving greater then 50 pixels and large areas involving more then 700 pixels.

The fine or small field accuracy tests were performed by rotating the star image in a circular path of fixed radius. The small circles were centered at five different locations on the CID array. Position data was recorded for three different star intensities and at three varying CID temperatures at each location. 60 positions around the circles were sampled five times each resulting in 300 data points per small circle. The mean of these five samples is the position output for each of the 60 positions.

The large field pointing tests were used to determine the relative pointing accuracy over a larger portion of the CID. The star image was rotated in a circular path with a radius of about 14 pixels. Position data was collected for five large circles centered at five different locations. See Figure 3-2.

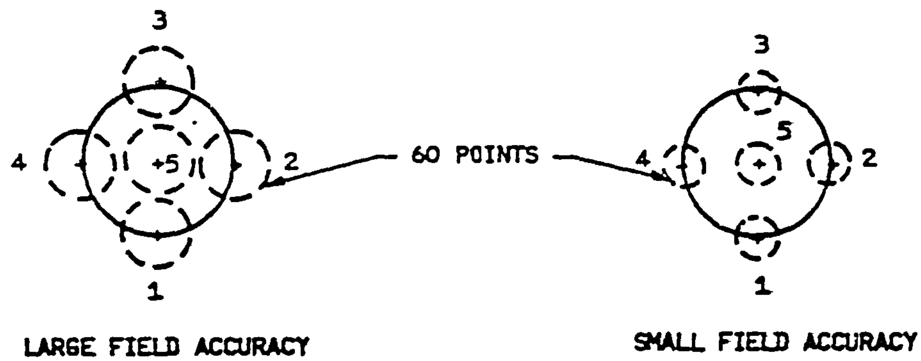

Figure 3-2. Pattern For Test Data

The circular motion of the star image was obtained by the wedge drive assembly for both the small and large field accuracy tests. Depending upon which wedge was used, either large or small circles could be traced. (See test equipment and procedure Section 2.0 for more details.) The voltage input to the star simulator was varied to obtain the three different light intensities. The CID temperature was controlled by a potentiometer setting on the CID electronic board which is connected to the computer interface box.

The data was collected and processed by the Z-80 microprocessor system. The four constants needed for the position interpolation mechanism were computed

iteratively in software. The constants were computed for each new location to avoid variances due to focus changes. The interpixel transfer function was assumed to be a straight line (Output vs. Displacement) over each half pixel of displacement. The four constants are used to normalize the output to the pixel dimension. The data was analyzed by applying the least square method to fit the 60 position points to a perfect circle. Appendix B discusses the arithematic used.

The center location and radius was computed for the circle. The displacement of each data point from this circle is the interpolation error for that position. The standard deviation of all data points is the interpolation error for that circle of data. These errors were computed twice, the first computation using all the position data accumulated and the second using only the position data deemed valid. Invalid data may have resulted from spurious noise spikes while reading or computing position and were identified by a high standard deviation of the five samples taken for that position. Individual data points consisting of five readings that had a standard deviation greater than one percent of a pixel were discarded in the second computation.

With the help of software, the equipment design allowed taking 300 points in about 10 minutes. Transcribing the data onto the floppy disk was the single most time consuming factor. This automation reduced the possibility of test errors from room temperature variation and mechanical instability of the system.

3.3.2 Pointing Accuracy Test Data

The pointing accuracy test data is summarized in Tables 3-5 thru 3-7. The raw data for a CID temperature of 0°C is contained in Section 4.0 of this volume. The total set of data is included in Volume II of this report. Note that all position, dimensional and error data was normalized to the pixel dimension of 20µm. The scaling for this system is 41.253 arc sec/pixel.

Table 3-5
SUMMARY DATA FOR
POINTING ACCURACY TESTS

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SUMMARY DATA FOR
POINTING ACCURACY TESTS

DATE

SMALL FIELD ACCURACY

DISK/ FILE #	CID TEMP °C	FOCUS REF DIMENSION MILS	STAR MAGNITUDE	Toff 5 Tr + Ti	Te Tr + Ti	NUMBER 2 READINGS	TD °/sec pix	INTERPOLATION CONSTANT Kx	Kx'	Ky	Ky'	MOVING pixels	CENTER LOCATION X	Y	STANDARD DEVIATION	POINTS IN ERROR					
																[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27 A [illegible]	10	+0 9	1 0	0 477 sec	0.0941 sec	32	0 95 x10^{5}	.337	281	378	236	2 102	[illegible]	[illegible]	1 510%	0	1	2	8	[illegible]	34
27 A 16	10	+0 9	2 85	0 187 sec	0.373 sec	128	0 22 x10^{5}	.337	281	378	280	2.100	[illegible]	[illegible]	1 528%	0	2	3	4	[illegible]	37
27 A 0[illegible]	20	+0 9	0.9	0 477 sec	0.0941 sec	32	1 0 x10^{5}	337	287	.378	280	2.103	[illegible]	[illegible]	1 447%	0	1	2	7	[illegible]	34
27 A-0[illegible]	20	+0 9	2 85	0 187 sec	0 373 sec	128	0 4 x10^{5}	337	287	378	280	2 102	[illegible]	[illegible]	1 953%	1	3	2	[illegible]	12	26
24 A-00	0	+0 8	1 1	0 477 sec	0.0941 sec	32	0 8 x10^{5}	.330	[illegible]	[illegible]	[illegible]	2 102	[illegible]	[illegible]	1 [illegible]%	0	0	3	5	17	32
29-A 03	0	10.8	2.8	0.187 sec	0 373 sec	128	0 2 x10^{5}	.330	[illegible]	370	236	2.100	[illegible]	[illegible]	1 442%	0	1	1	10	14	35
24 A 0[illegible]	0	10.8	6 0	1 354 sec	1 911 sec	384	0 12 x10^{5}	330	294	370	236	2 103	[illegible]	[illegible]	2 170%	2	2	5	10	[illegible]	20
27 A [illegible]	10	10 8	1 0	0 477 sec	0 0941 sec	32	0.75 x10	.330	.294	370	.236	2 102	[illegible]	[illegible]	1 303%	0	0	2	8	15	37
24 A-05	10	10.8	2 8	0 187 sec	0.373 sec	128	0 2 x10^{5}	330	294	370	236	2 101	[illegible]	[illegible]	1 453%	0	0	2	8	18	29
24 A 0[illegible]	10	+0.8	6 1	1 354 sec	1 911 sec	384	0 2 x10^{5}	.330	294	370	236	2.102	[illegible]	[illegible]	2 881%	5	2	9	5	[illegible]	12
29-A 09	20	+0 8	1 0	0 477 sec	0.0941 sec	32	1 0 x10^{5}	.330	294	370	236	2 105	[illegible]	[illegible]	1 329%	0	0	2	6	18	33
24 A [illegible]	20	+0 8	2 85	0 187 sec	0 373 sec	128	0 47 x10^{5}	.330	294	370	236	2 103	[illegible]	[illegible]	1 457%	0	0	2	9	15	32
24 A-11	20	+0.8	6 1	1 354 sec	1 911 sec	384	0 58 x10	.330	294	370	236	2 112	[illegible]	[illegible]	5.190%	12	[illegible]	4	7	9	10
12 B 01	0	+0 3	0.85	0 477 sec	0.0941 sec	32	0 8 x10^{5}	3.7	255	.406	265	2.088	[illegible]	[illegible]	1 846%	0	2	3	12	22	20
12-B-0[illegible]	0	+0.3	2 6	0 187 sec	0 373 sec	128	0 19 x10^{5}	.317	.255	.406	265	2.089	[illegible]	[illegible]	1 614%	0	1	2	[illegible]	19	26
12 A 03	0	+0 3	5 9	1 354 sec	1.911 sec	384	0.2 x10^{5}	317	.255	.406	265	2 0[illegible]	[illegible]	[illegible]	1 733%	0	1	3	11	17	25
12 B 04	10	+0.3	0 9	0 477 sec	0 0941 sec	32	0 8 x10^{5}	.317	255	406	265	2 090	[illegible]	[illegible]	1 729%	0	1	3	10	17	28
12 B 0[illegible]	10	+0 3	2 60	0.187 sec	0 373 sec	128	0 27 x10^{5}	.317	255	.406	265	2 090	[illegible]	[illegible]	1.955%	0	1	3	9	24	17
12 B 06	10	+0 3	5 8	1 354 sec	1 911 sec	384	0 24 x10^{5}	.317	255	406	265	2 093	[illegible]	[illegible]	2 515%	3	4	6	8	17	20
12 B 07	20	+0 3	0 9	0 477 sec	0.0941 sec	32	1 0 x10^{5}	.317	255	406	265	2 093	[illegible]	[illegible]	1 637%	0	0	3	13	[illegible]	24
12 B 08	20	+0.3	2 9	0 187 sec	0 373 sec	128	0 40 x10^{5}	.317	255	406	265	2 093	[illegible]	[illegible]	2 437	0	6	9	15	[illegible]	15

Table 3-6
SUMMARY DATA FOR POINTING ACCURACY TESTS

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SUMMARY DATA FOR
POINTING ACCURACY TESTS

DATE [illegible]
SMALL FIELD ACCURACY

MSA/FILE #	CID TEMP °C	FOCUS REF DIMENSION MILS	STAR MAGNITUDE	Tieff 5 Ir + 1t	To Ir + 1t	[illegible] 2 READINGS	SB [illegible]/sec pts	INTERPOLATION CONSTANT E_x	E_x'	E_y	E_y'	RADIUS pixels	CENTER LOCATION X	Y	STANDARD DEVIATION	POINTS IN ERROR >σ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 A 08	0	+1 0	1 10	0 477 sec	.0941 sec	32	0 75 x10^6	347	.275	408	298	2 107	131 [illegible]	164 [illegible]	1 744 %	0	1	5	10	19	22
12 A 10	0	+1 0	2 85	0 187 sec	0.373 sec	128	0.18 x10^6	347	275	408	295	2 106	131 [illegible]	164 [illegible]	1.716 %	0	2	3	8	7	22
12-B-10	0	+1 0	6 0	1 354 sec	1 911 sec	384	0 12 x10^6	347	275	408	298	2 100	131 [illegible]	164 [illegible]	2 448 %	2	2	6	13	7	25
12-A-03	10	+1 0	1 0	0 477 sec	0.0941 sec	32	0.8 x10^6	347	.275	408	.298	2 107	131 [illegible]	[illegible]	1 721 %	0	0	8	7	14	27
12 A-01	10	+1 0	2 8	0 187 sec	0 373 sec	128	0 25 x10^6	347	275	.408	.298	2 100	[illegible]	[illegible]	1 897 %	1	1	4	9	14	27
12-A-02	10	+1 0	6 0	1 354 sec	1 911 sec	384	0 26 x10^6	347	.275	408	.298	2 094	[illegible]	[illegible]	2 603 %	9	3	4	10	13	15
12 A-07	20	+1 0	1 10	0 477 sec	.0941 sec	32	1.0 x10^6	347	275	408	298	2 104	[illegible]	[illegible]	1.718 %	0	1	5	11	12	28
12-A-05	20	+1 0	2 85	0 187 sec	0.373 sec	128	0 41 x10^6	.347	275	.408	.298	2 098	[illegible]	[illegible]	3 187 %	1	0	6	8	7	26
12-A-06	20	+1 0	6 1	1 354 sec	1 911 sec	384	2.65 x10^6	347	27	408	298	2 095	[illegible]	[illegible]	4 271 %	9	4	8	7	10	7
12-A-11	0	-0.5	1.0	0 477 sec	0.0941 sec	32	0 8 x10^6	298	255	367	302	2 095	[illegible]	[illegible]	1.975 %	0	2	3	13	10	21
12 A-10	0	-0 5	2 75	0 187 sec	0 373 sec	128	0 16 x10^6	298	255	367	302	2 096	[illegible]	[illegible]	2 000 %	0	3	5	13	9	28
27-A 06	0	-0 5	6 0	1 354 sec	1 911 sec	384	0 11 x10^6	.298	255	367	302	2 101	[illegible]	[illegible]	2 338 %	0	5	6	13	15	17
27 A 02	10	-0 5	1 0	0 477 sec	0.0941 sec	32	0 80 x10^6	298	.255	367	.302	2 094	[illegible]	[illegible]	1 953 %	1	2	4	10	11	25
27-A-01	10	-0 5	2.75	0 187 sec	0 373 sec	128	0 20 x10^6	298	255	367	.302	2. 098	[illegible]	[illegible]	1 927 %	0	4	2	8	18	22
27-A-03	10	-0.5	6 0	1 354 sec	1 911 sec	384	0 20 x10^6	.298	255	367	302	2 095	[illegible]	[illegible]	2 694 %	2	6	9	7	15	16
27-A 05	20	-0.5	1 0	0 477 sec	0.0941 sec	32	1 0 x10^6	298	255	367	302	2.095	[illegible]	[illegible]	1 942 %	1	2	3	8	19	27
27 A 04	20	-0 5	2 75	0 187 sec	0 373 sec	128	0 51 x10^6	.298	255	367	.302	2 096	[illegible]	[illegible]	1.934 %	1	2	4	8	18	22
27-A 06	20	-0.5	6	1 354 sec	1 911 sec	384	0 [illegible] x10^6	298	255	367	302	2 087	[illegible]	[illegible]	4 941 %	19	5	12	10	5	6
27 A 07	0	+0 9	1 0	0 477 sec	0.0941 sec	32	0 8 x10^6	337	287	378	280	2 099	[illegible]	[illegible]	1 375 %	0	0	2	7	15	34
27-A 08	0	+0 9	2 8	0 187 sec	0 373 sec	128	0 17 x10^6	337	287	378	280	2 099	[illegible]	[illegible]	1 330 %	0	0	2	5	11	35
27 A-09	0	+0 9	5 5	1 354 sec	1 90 sec	384	0 10 x10^6	337	287	.378	280	2 101	[illegible]	[illegible]	4.912 %	19	3	2	4	13	14

Table 3-7
SUMMARY DATA FOR POINTING ACCURACY TESTS

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SUMMARY DATA FOR POINTING ACCURACY TESTS

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LARGE FIELD ALIGNMENT

MESA/FILE #	CID TEMP °C	FOCUS OFF DIMENSION MILS	STAR MAGNITUDE	Teff 5 Tr + Ti	Tc Tr + Ti	MICRO 2 READINGS	ID	Interpolation Constant kx	kx'	ky	ky'	Radius Pixels	Center Location X	Center Location Y	Standard Deviation	Points in Error [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-01	0	4.6	27	0.187 sec	0.372 sec	128	[illegible]	.309	.317	.363	.342	14.563	[illegible]	[illegible]	2.023%	1	0	4	9	20	16
[illegible]-02	0	3.0	265	0.187 sec	0.372 sec	128	[illegible]	290	.226	.347	.270	14.557	[illegible]	123.2544	2.193%	2	3	2	15	11	20
[illegible]-03	0	-1.1	27	0.187 sec	0.372 sec	128	[illegible]	254	294	.316	.294	14.547	[illegible]	138.1642	1.813%	1	1	2	8	24	8
[illegible]-04	0	-0.8	27	0.187 sec	0.372 sec	128	[illegible]	-262	[illegible]	362	.262	14.557	[illegible]	123.5462	3.150%	6	2	4	[illegible]	11	15
[illegible]-05	0	0.0	255	0.187 sec	0.372 sec	128	[illegible]	288	276	.300	.268	14.561	[illegible]	[illegible]	1.992%	0	4	2	[illegible]	19	19

3.3.2.1 Description of Summary Sheet (Tables 3-5 through 3-7).

1) Disk/File #: All data is stored on floppy disks and identified by the file number shown.

2) CID-TEMP: The temperature of the CID is set by a potentiometer on the CID electronic board. Temperature shown is in degrees centigrade.

3) Focus REF DIM: The lens focus is monitored by a micrometer for each new circle position. Reference focus dimension is shown in mils.

4) Star magnitude: This is computed by an equation developed in Section 5.32 of BASD procedure No. 2332-101 (see Appendix A).

$$Mv = \ln \left(\frac{4.465 \times 10^7 \text{ NDRO } (Tr + 2Ti)}{S\ (f/n)^2}\right) + \ln 2.51$$

4.465×10^7 is a constant for the interpolation Algorithm
NDRO = total number of samples in first and second read
Tr = total time spent taking the first and second read
Ti = integration time between the first and second read
S = signal in e^- ($179.5e^-$/bit)
f/n = lens f-number setting.

Tr = tr NDRO   tr = time for one read of track pattern (12 pixels) = 2.9×10^{-3} sec

5) Effective Charge Integration time (Tieff) = .5 Tr + Ti: This is the effective charge integration time for a given total read time and integration time (Ti) between both readings (See Figure 3-3).

6) Update Time (Tu) is the total time taken to obtain a reading for tracking information. (See Figure 3-3).

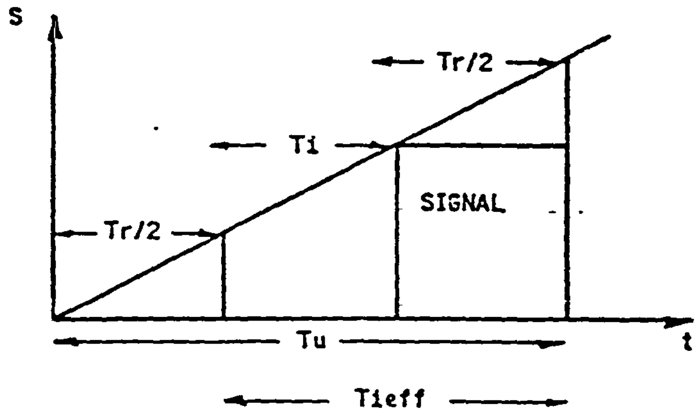


Figure 3-3 Update Time

7) Track NDRO: The number of readings taken in the read time Tr during the track cycles.

8) Id (e^-/sec-pixel): The dark current generation due to the effective charge integration time (Tieff)

$$Id = \frac{4S}{NDRO\ (Tr + 2\ Ti)} \qquad \frac{e^-}{sec\text{-}pix}$$

where

NDRO total # of readings for first and second reads

S is the output signal in e^-

(Invalid data is excluded from the following column)

9) Center Location (x,y): The center coordinates of each of the small or large circles.

10) Radius (pixels): The mean radius of the circle computed from the least square method of fitting the sixty points to a circle.

11) Interpolation Constants: Computed iteratively in software to (K_x, K_x^1, K_y, K_y') normalize the transfer functions to the pixel dimensions.

12) Standard Deviation: The deviation of position points from the least squares fit circle positions.

13) Points with Error >: A histogram of all sixty points for the number of points with deviations in the following ranges, .05 to .04, .04 to .03, .03 to .02, .02 to .01, and .01 to .00.

3.3.2.2 Description of Computer Data Sheet (Test Data Section 4.0 of This Volume and Volume II)

Each data printout contains information on one circle of 300 position points. Typical data includes the number of NDRO's, integration times and thresholds for coarse, fine and track modes. Also, each time a position is sampled, the corresponding temperature of the CID, wedge angle, dark current generation, star magnitude and positions are recorded.

Computer Printout Details:

A computer sheet containing the following details is printed for each circle.

- NDRO's is the total number of samples in the first read only, for coarse, fine and track. (The same number is used for the second read but is not printed.)

- Integration Delay is the time, in seconds, between the first and second read for coarse and fine acquisition and track.

- Thresholds is the minimum threshold, in electrons, for acquisition in coarse, fine and track modes.

- Constants are the four constants (Kx, Kx', Ky and Ky') used to normalize the transfer function to the pixel dimension.

Tabulated Data

- Temperature is the CID temperature given in degrees centigrade.

- Angle is the deviation wedge angle potentiometer output. The wedge angle rotates 6° for each position sample. The potentiometer to wedge gear ratio is 5:1, hence for one rotation of the continuous pot, the wedge rotates through 72°.

- Dark Current is the dark current generated in the effective charge integration time (Tieff). Units are in e^-/sec-pix.

- Star Magnitude is computed using a formula developed in Section 5.32 of procedure No. 2332-101 (Appendix A.) See Paragraph 3.3.2.1 item 8.

- Reference defines the coordinates for the origin from which the interpolated star position will be computed. It also defines the location of the star to the nearest half pixel.

- Position defines the coordinates of the computed star position. These are the sum of the reference location and the interpolated position of the star. Each data point is the mean of 5 position readings.

- Standard deviation refers to the variation in the five readings defining the position.

Reduced Data

- Delta Ri are the errors for the 60 data points shown in the first tabulation. Reading the data from left to right corresponds to the sequence of the coordinate data tabulated above. The error shown is the straight line deviation of the coordinate position from a best fit circle.

- XO, YO, RO are the center coordinates and radius for the best fit circle as determined by the least square method.

- Standard deviation is the standard deviation of the sixty data points from the best fit circle.

- Histogram Deviation is a tabulation of the number of Delta Ri that fall within the five ranges; .00 to .01, .01 to .02, .02 to .03, .03 to .04, .04 to .05. The reduced data is computed a second time with bad data removed as described in paragraph 3.3.1.

3.3.2.3 Plots

The plots of small and large circles consist of all 60 data points. Points 23, 27 and 29 did not plot because of a software problem. The standard deviation printed below the plot is computed from valid data points only. The following are also included: the disk/file number of the corresponding data, lens f/n number, focus reference dimension, the four interpolation constants, star intensity and the temperature of CID during test.

Although the plots are not useful for quantitative evaluation of performance, they were extremely useful in troubleshooting the hardware/software and indetermining constants. See test data.

3.3.3 Star Magnitude Calibration

A star magnitude calibration was conducted to verify the star magnitude equation

$$Mv = \ln \left(\frac{4.465 \times 10^7 \ NDRO\ (\tau r + 2\ Ti)}{S\ (f/n)^2}\right) + \ln 2.51$$

The star magnitude varies as a logrithmic function so that

$$(2.512)^{Mv}\ (1 \times 10^{-12}) = \phi_{Mv} \ \text{watts/cm}^2$$

where here a 0Mv star is estimated at 1×10^{-12} watts/cm^2:

A UDT photometer measured the flux output of the star light for an intensity at a zero magnitude star. A factor of 10 corresponds to approximately a factor of 2.5 change in ϕ_{Mv}. Since 10 percent of maximum star was measured to be 4.92 Mv, the maximum star corresponds to 4.92 - 2.5 ~ 2.4 Mv and minimum star (1 percent of maximum) would correspond to 7.4 Mv. These star magnitudes closely approximate the magnitude (to about ±.5 Mv) computed by the software formula for Mv above.

3.3.4 Noise Equivalent Displacement (NED) and Update time (Tu)

The noise equivalent displacement (NED) is the random error in star image centroid position resulting from detector and circuit noise. This evaluation measured NED as a function of update time (Tu). The noise equivalent displacement analysis is based on (RMS) noise which decreases as the number of samples read. The number of samples are given by:

$$NDRO = \frac{Tu - Ti}{tr}$$

where

NDRO is the number of samples for the first and second readout

Tu is the update time. See Figure 3-3.

Ti is the integration time between reads
tr is the read time per sample of the track subarray (2.9×10^{-3} sec).

The test involved recording approximately 25 samples of star position for a stationary star in the track mode. Data was collected for the conditions of zero degree centigrade (CID temperature), minimum star magnitude (~ +5.8 to +6 Mv) and minimum integration delay time. Different number of NDRO's were used for each set of 25 samples to vary the update time as snown by the equation above.

The results of tnis test are shown in Table 3-8.

3.3.5 Map for CID Region with High Current Generation

Some of the raw data plots show highly erratic data points as a result of abnormally high local current generation in the CID. This is particularly evident in the small circle data taken in the first position.

A fine map was taken in this region (see Volume II of this report) in an attempt to quantify the anommaly. The data shows differential dark current in the pixels of approximately 4×10^5 e^- and $10^6 e^-$ at 10°C and 20°C respectively. A typical map would show variations of less than 10^5 e- under the same conditions.

3.3.6 Transfer Function Linearity

Analysis has shown that BASD's interpixel transfer function non-linearity should not exceed ±1 percent for image diameters greater than one pixel. Several sets of data were analyzed and plotted against a straight line function. Figure 3-4 shows the typical deviation from a straight line for this data and shows a maximum deviation of approximately ± 0.5 percent.

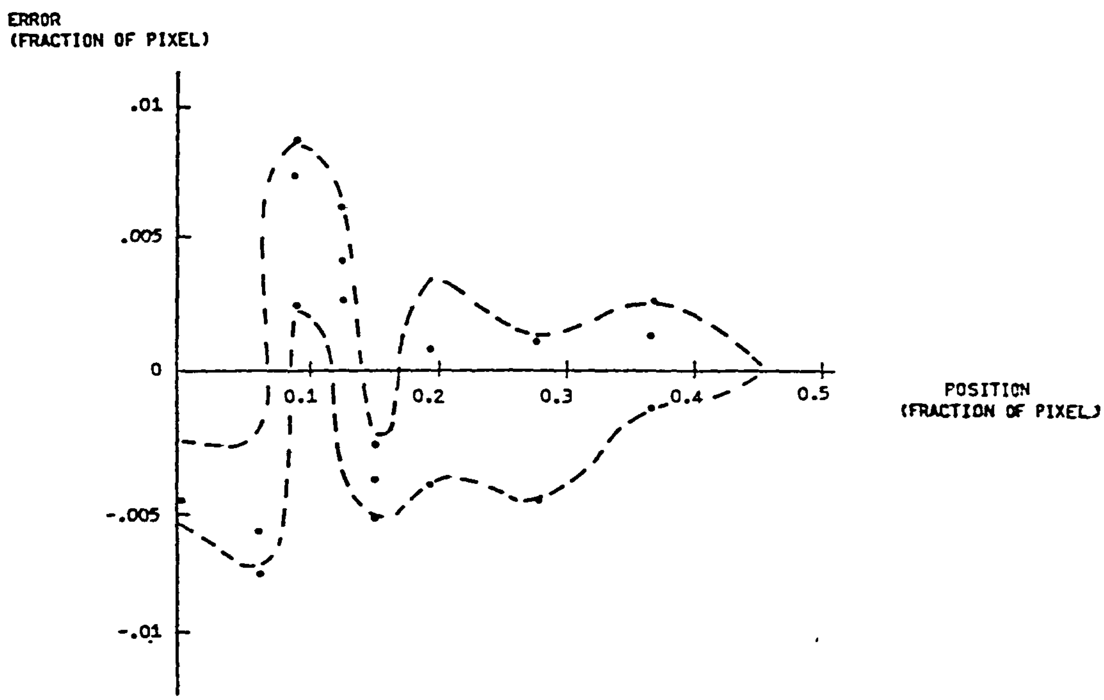


Figure 3-4. Typical Deviation From a Straight Line For Data

Table 3-8

NED Data

Ti = ≡ ~ .4 msec

Mv = +5.9

		NED	
NDRO	Tu (sec)	x	y
10	.080	.0695	.0431
1D	.150	.0215	.0208
30	.250	.0086	.0083
4E	.400	.0062	.0045
60	.500	.0043	.0040
75	.600	.0043	.0037
8A	.700	.0028	.0046
9C	.800	.0028	.0025
AD	.900	.0030	.0031
C3	1.000	.0032	.0029
FF	1.300	.0032	.0029

A plot of NED vs. update time is shown in Figure 3-5. This plot shows that a noise equivalent displacement of less than 1 percent of a pixel can be met with update times as low as .23 sec. In this case, the best performance was achieved with Ti minimum and Tu of .8 sec, for a NED of 0.25% of a pixel. NED for the x axis is higher than NED for the y axis because of a misalignment in this particular tracker. Proper alignment should yield a uniform NED for both axes.

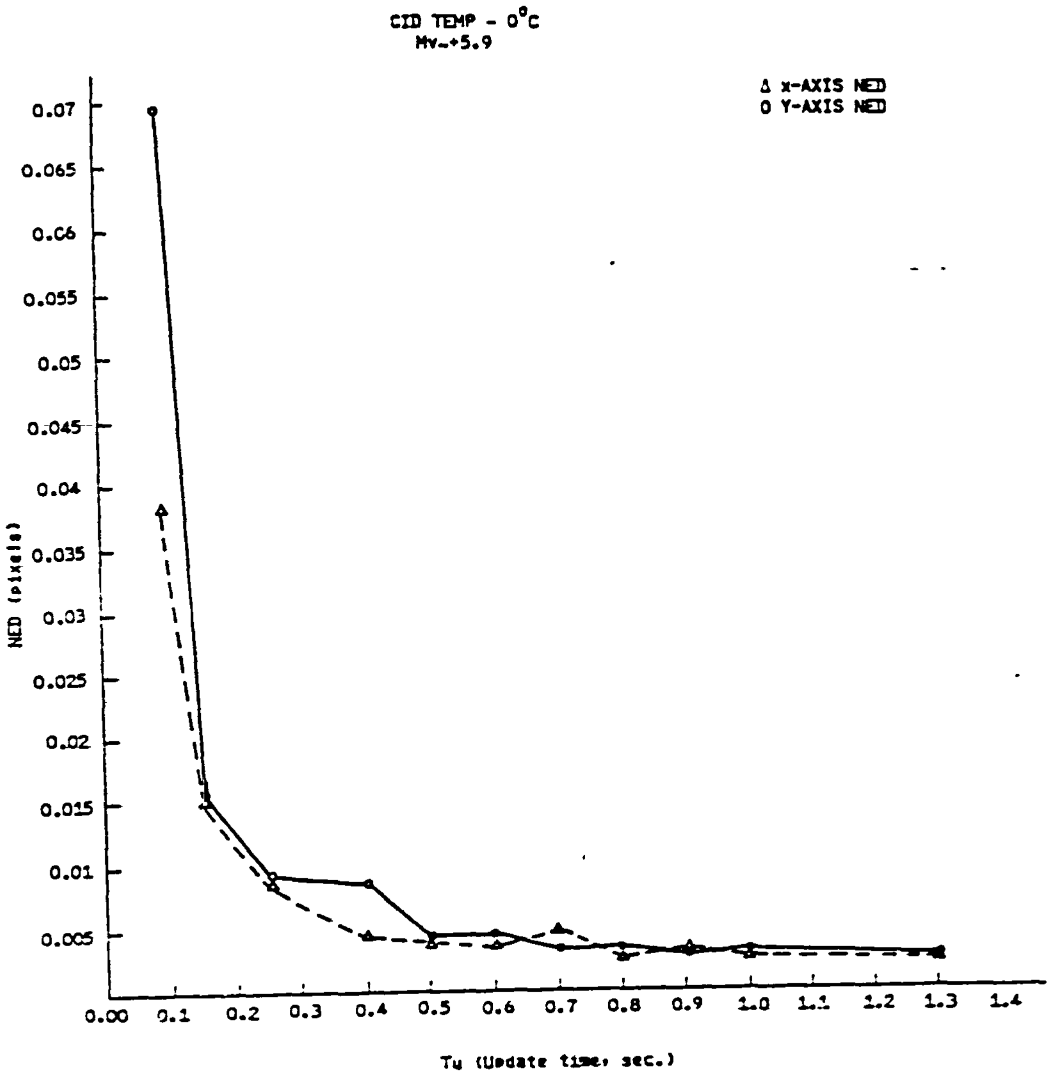


Figure 3-5. Noise Equivalent Displacement (NED) Vs. Update Time

3.3.7 Evaluation Of Error Sources

An extensive evaluation and exploratory test program was conducted by BASD in order to identify the error sources. The conclusion drawn from this program is that the accuracy is limited by our current mechanization rather than by uncertainties in the CID (except for bad areas in the CID). A solution has been defined, but not yet implemented and tested. This problem and solution are briefly summarized below.

a) The CID design provides access to a 4 x 4 block of pixels with one address.

b) BASD's mechanization requires sampling a dark pixel for use as a reference for common mode noise rejection.

c) The dark pixel is sampled from the same 4 x 4 block which is used to sample the star signal pixels to conserve time. In some cases this results in sampling "dark" pixels adjacent to pixels on which the star is imaged.

d) Sufficient pixel-to-pixel cross talk exists, internal to the CID, so that a pixel adjacent to the star image also receives star signal.

e) The cross talk into the dark reference pixel results in biasing the transfer function differently for varying star position and results in position bias errors.

The problem can be minimized by advancing the data block when taking dark data so that the dark pixel is never sampled adjacent to the signal pixels. Although this requires more time, it is estimated that the resultant increase in NED will be less than 10 percent for a given update time.

Other potential sources of error remain to be investigated.

3.3.8 Conclusion for Pointing Accuracy Test

The accuracy for stars brighter than 3 Mv is approximately ±0.0178 pixels over a CID temperature range of 0°C to 20°C. The accuracy for all data at 0°C is better than ±0.02 pixels. The accuracy for the 6 Mv star degrades with CID temperature.

From the data of Tables 3-5 through 3-7 the cross talk is quite evident. Note that the dark current is highest for the bright star in all sets of data. This results from the higher amount of signal coupled with the dark reference pixel from which dark current is computed. The dark current variation for the raw data sets is also indicative of this effect.

The temperature dependancy of the 6 Mv star data is much greater than expected (if it is totally due to CID dark current variations). This would indicate a mean pixel-to-pixel variation in dark current of approximately 5 percent. This is excessive compared to the 2.2 percent measured on the 128 x 128 CID. It is not known at this time whether or not the cross talk problem may be amplifying these effects. Before further conclusions can be drawn, further investigation needs to be made into this problem and into the problem of high current generation spots on the CID.

The cross talk was previously taken into account on a qualitative basis in developing algorithms for a linear transfer function. However, it was not considered when the common mode noise rejection was introduced.

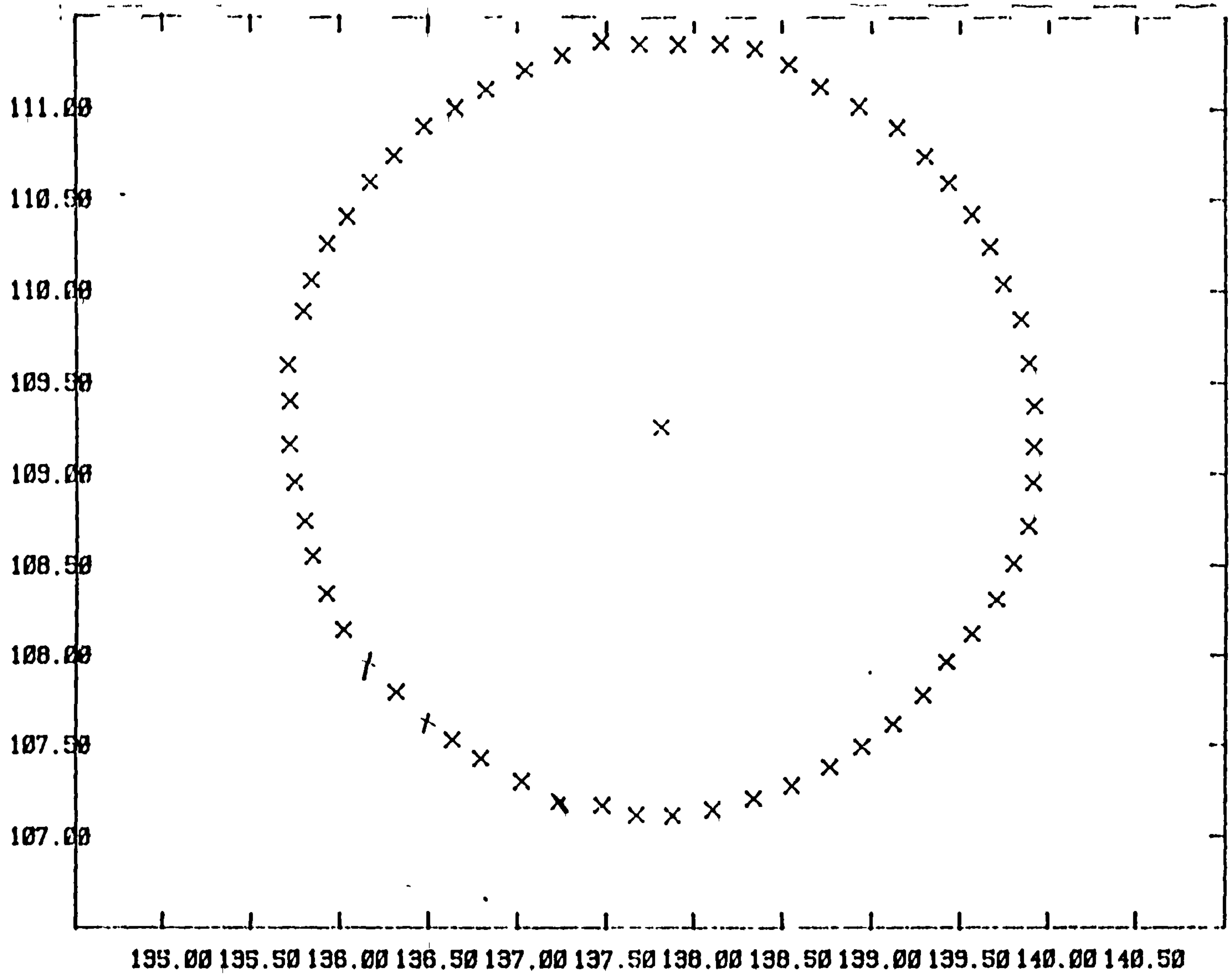
Except for the cross-talk bias effects, the CID tracker performed as expected within the limits to which the acquisition and track algorithms were refined for this test program. The test approach and associated hardware developed by BASD proved efficient and accurate. There is no indication that test errors are influential in the accuracy test data. However, further investigation in this area remains to be completed. The test software developed under this contract results in a hard copy of all pertinent data. Except for the time required to compute constants, a circle of 60 data points can be taken and analyzed in approximately 20 minutes with an estimated accuracy of approximately 0.1 seconds of arc.

Section 4
POINTING ACCURACY DATA AT 0°C

4.1 0°C TEST DATA

The data in this volume has been limited to the accuracy test at 0°C because it is of primary interest and the total set of data would not conveniently fit in this section.

Volume II contains a full set of data. The printout is described in Paragraph 3.3.2.2.



POSITION #1 S.D=1.744%

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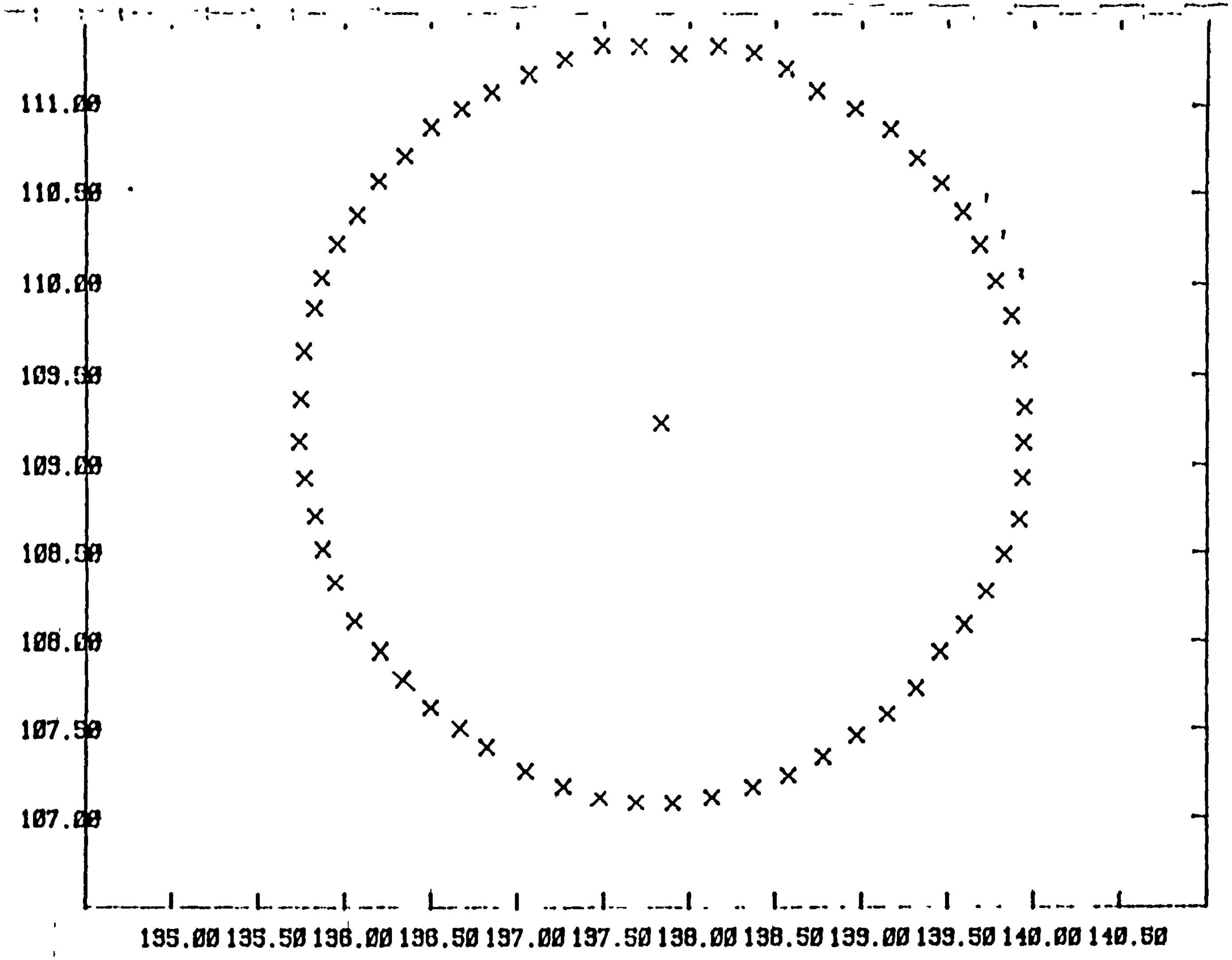
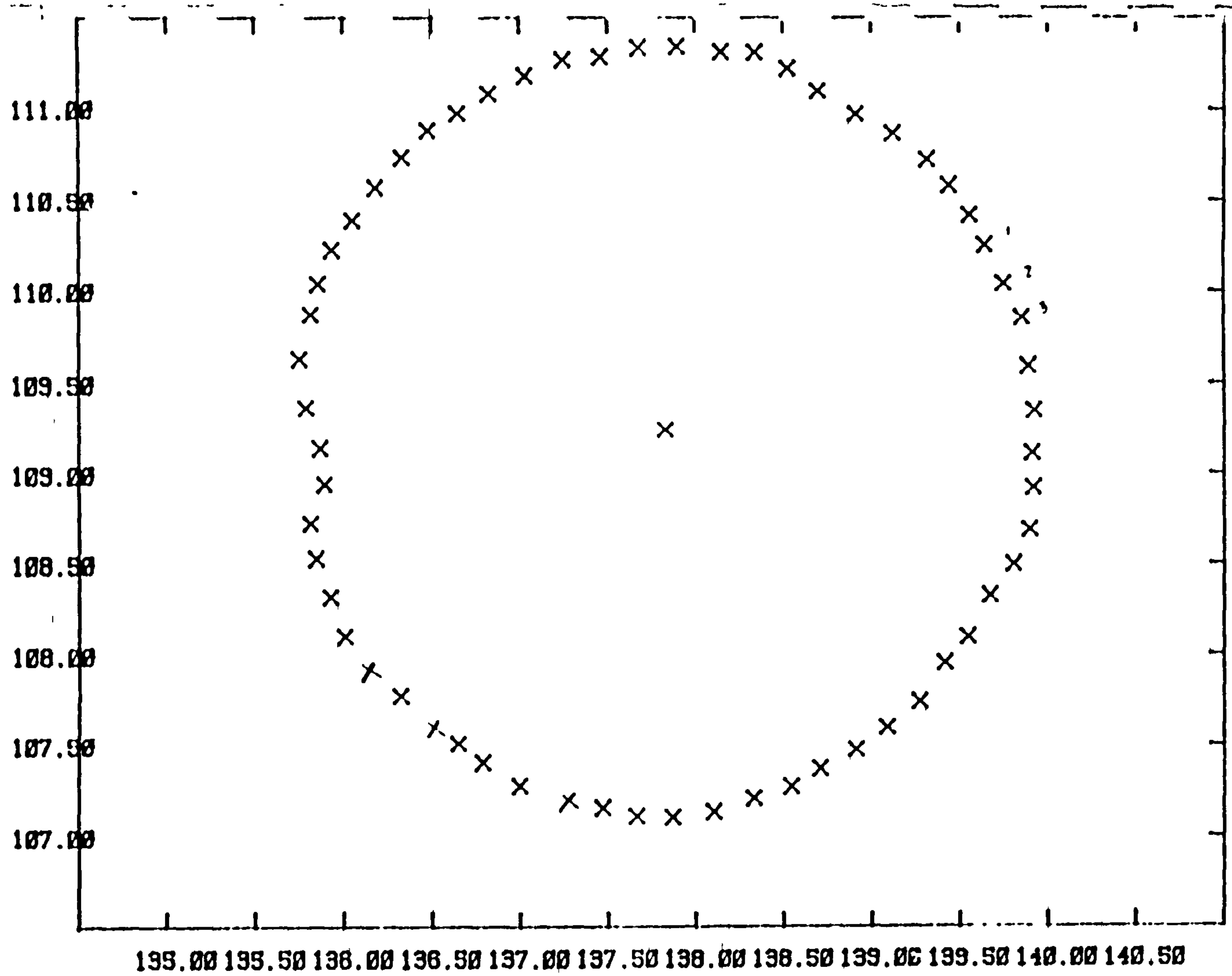
12-0-00 F2.8 +1.0M 2 K=.347.275.408.298 100% 0°C.



POSITION #1 S.D= 1.716%

12-B-10 F2.8 +1.0M 2 K=.347.275.408.298 10% 0°C

TR81-04



POSITION #1 S.D= 2.948%

12-B-11 F2.8 +1.0M 2 K=.347.275.408.298 <1% 0°C

TR81-04

3

Disk 12-A   Track data file TDATA00

	Coarse	Fine	Track	
NDOT:	1.0	1.0	16.0	
Integration delay:	.1170E+00	.4564E+00	.1344E 02	
Thresholds:	.1838E+06	.9190E+05	.7352E+06	
Constants:	.34700	.27500	.40800	.29800
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.318	1.806	.6948E+05	1.099	139.5	110.0	139.6622	110.2473	.6346E-03	.2245E-02
.352	8.179	.7952E+05	1.147	140.0	110.0	139.7406	110.0392	.1429E-02	.9772E-03
.347	14.372	.8142E+05	1.134	140.0	110.0	139.8365	109.8477	.7037E-03	.1570E 02
.403	20.706	.6966E+05	1.009	140.0	109.5	139.8852	109.6119	.8536E 03	.8145E-03
.352	26.947	.6101E+05	1.037	140.0	109.5	139.9153	109.3721	.1084E-02	.7529E 03
.408	33.236	.5145E+05	1.199	140.0	109.0	139.9131	109.1529	.1495E 02	.6431E 03
.355	39.512	.5212E+05	1.179	140.0	109.0	139.9067	108.9545	.1999E-02	.1255E-02
.383	45.770	.5260E+05	1.133	140.0	109.0	139.8795	108.7185	.2065E-02	.1207E 02
.333	52.061	.6455E+05	.999	140.0	108.5	139.7959	108.5105	.1325E 02	.1 021 02
.434	58.373	.9211E+05	1.238	140.0	108.0	139.6992	108.3108	.1640E-02	.9286E-03
.408	64.574	.8607E+05	1.159	139.5	108.0	139.5627	108.1170	.8652E 03	.1414E-02
.411	70.870	.8942E+05	1.138	139.5	108.0	139.4204	107.9650	.6777E 03	.1413E-02
.403	1.816	.1054E+06	1.204	139.0	108.0	139.2852	107.7797	.9091E-03	.2292E-02
.299	8.171	.1007E+06	1.022	139.0	107.5	139.1205	107.6107	.1268E 02	.1109E-02
.313	14.370	.1011E+06	1.010	139.0	107.5	138.9453	107.4879	.3944E-03	.1530E-02
.260	20.722	.1023E+06	1.253	139.0	107.0	138.7635	107.3771	.1299E-02	.1993E-02
.321	26.966	.8839E+05	1.164	138.5	107.0	138.5512	107.2760	.7326E-03	.1560E 02
.299	33.235	.8346E+05	1.166	138.5	107.0	138.3360	107.2065	.1040E-02	.1326E-02
.299	39.535	.8449E+05	1.190	138.0	107.0	138.1015	107.1459	.5468E 03	.1831 02
.317	45.700	.8700E+05	1.204	138.0	107.0	137.8756	107.1170	.1990E 02	.6131E 03
.321	52.090	.9240E+05	1.243	138.0	107.0	137.6670	107.1201	.2028E 02	.3130E 02
.293	53.327	.8186E+05	1.147	137.5	107.0	137.4761	107.1690	.1227E-02	.5860E-03
.304	64.624	.8298E+05	1.192	137.0	107.0	137.2380	107.2157	.7109E-03	.1225E-02
.330	70.855	.8907E+05	1.103	137.0	107.0	137.0217	107.2907	.1009E-02	.8350E-03
.332	1.808	.9623E+05	1.025	137.0	107.5	136.7944	107.4249	.6801E-03	.1241E 02
.271	8.168	.7057E+05	.966	136.5	107.5	136.6331	107.5257	.1284E 02	.7566E 03
.369	14.361	.1442E+06	1.205	136.5	108.0	136.4933	107.4759	.6562E-01	.2974E+00
.425	20.736	.1020E+06	1.245	136.0	108.0	136.3197	107.7963	.5107E 03	.8916E 03
.412	26.963	.9979E+05	1.105	136.0	108.0	136.1757	107.9705	.5512E-03	.1409E 02
.417	33.254	.9320E+05	1.100	136.0	108.0	136.0165	108.1437	[illegible]	[illegible]
.361	39.543	.7729E+05	1.061	136.0	108.5	[illegible]	108.3436	[illegible]	[illegible]
.347	45.731	[illegible]	.991	136.0	108.5	[illegible]	108.5176	[illegible]	[illegible]
.304	52.077	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	108.7407	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.341	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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.30	70.	. E+05	1.0	1	5	1 28	9.39	1E-0	.18 02
.318	1.827	.1324E+06	1.101	136.0	110.0	135.6401	109.5202	.218 E+00	.2592E+00
.316	8.105	.7952E+05	1.148	136.0	110.0	135.7918	109.8881	.1430E 02	.5074E 03
.352	14.386	.7739E+05	1.174	136.0	110.0	135.8339	110.0562	.1273E 02	.7991E 03
.310	20.754	.7682E+05	1.152	136.0	110.0	135.9279	110.2605	.1208E-02	.2107E-02
.282	27.004	.4537E+05	.923	136.0	110.5	136.0419	110.4071	.1549E 02	.1 [illegible] 02
.327	33.272	.5552E+05	.933	136.0	110.5	136.1720	110.5965	.9011E 02	.[illegible] -02
.274	39.540	.6147E+05	1.146	136.0	111.0	136.3055	110.7459	.8787E 03	.17 [illegible] 02
.288	45.832	.7107E+05	1.027	136.5	111.0	136.4740	110.9062	.9205E 03	.18[illegible] 02
.285	52.090	.7712E+05	1.069	136.5	111.0	136.6491	111.0025	.5618E-03	.1[illegible] 02
.338	58.381	.8732E+05	1.154	137.0	111.0	136.8267	111.1027	.1462E 02	.2074E 02
.330	64.630	.8604E+05	1.136	137.0	111.0	137.0395	111.2088	.1427E-02	.2[illegible] 02
.304	70.898	.8564E+05	1.142	137.0	111.0	137.2541	111.2922	.4718E-03	.[illegible]-03
.332	1.827	.8767E+05	1.105	137.5	111.0	137.4706	111.3673	.1190E-02	.1154E 02
.288	8.104	.9820E+05	1.063	138.0	111.5	137.6825	111.3550	.9423E-03	.1310E-02
.270	14.386	.9324E+05	1.035	138.0	111.5	137.9075	111.3533	.1442E-02	.2494E 02
.262	20.752	.8944E+05	1.123	138.0	111.0	138.1468	111.3590	.1111E-02	.1680E 02
.310	26.986	.8502E+05	1.112	138.5	111.0	138.3423	111.3291	.9717E-03	.1767E 02
.327	33.265	.8310E+05	1.097	138.5	111.0	138.5389	111.2436	.1027E-02	.1081E-02
.296	39.552	.9170E+05	1.149	139.0	111.0	138.7150	111.1207	.124 E 02	.9235E 03
.243	45.821	.8400E+05	1.111	139.0	111.0	138.9258	111.0126	.7061E-03	.5726E 03
.276	52.069	.7626E+05	1.089	139.0	111.0	139.1413	110.9025	.1229E-02	.1176E 02
.226	58.420	.6274E+05	1.123	139.0	111.0	139.3011	110.7414	.1065E-02	.2227E 02
.276	64.623	.4873E+05	.918	139.5	110.5	139.4330	110.5913	.5890E-03	.1098E 02
.276	70.862	.4235E+05	.903	139.5	110.5	139.5607	110.4203	.4320E 03	.[illegible] 03

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delta ri

	1	2	3	4	5	6
0	.00458	-.02192	.00778	.00016	.00311	.00011
1	[illegible]	.03219	.01491	.00580	[illegible]	-.04345
2	.02091	.01123	-.00787	-.00243	.00418	[illegible]
3	.01906	.02750	[illegible]	.00074	.00548	[illegible]
4	.02012	-.02169	.00974	.02879	-.03586	-.00757
5	-.01896	-.02221	-.03855	-.02269	-.01236	-.01331
6	.07084	.00025	.01756	.01932	-.00394	.00429
7	.00449	.01011	.01399	-.01920	-.01158	.00043
8	.02062	.00641	.00921	.02155	.03252	.00762
9	.03426	-.02550	.01113	.00114	-.00379	-.00301

o= 137.0051   ,o= 102.2547   ro= 2.11037780   std.dev.= .02334190

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	2	1	5	12	15	25	0

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delta ri

	1	2	3	4	5	6
0	-.00716	-.02445	.00534	.00209	.00111	-.00160
1	.01114	.03120	.01437	.00582	.016.4	-.04245
2	.01931	'.00902	-.00428	.00096	.00821	.01001
3	.02431	.03340	.03491	.00767	.01310	.00423
4	.01206	.01338		.02007	.0,700	.00235
5	.01005	-.01337	-.02982	.01415	-.00404	-.00531
6		.00738	.02433	.02560	.00191	.00857
7	.009,6	.01426	-.01038	-.01121	-.00918	.00221
8	.02981	-.00574	-.00908	.02115	.03172	.00843
9	.03501	.02748	.00096	.00351	-.00748	.00557

o= 137.8101 .o= 109.2574 r= 2.10721636 std.dev.= .01744137

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	5	10	14	28	2

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TR81-04

Disk 12-B Track data file TDA1A10 Position #1

	Coarse	Fine	Track	
NDROI	1.0	1.0	64.0	
Integration delay:	.1160E+00	.4564E+00	.1344E-02	
Thresholds:	.2757E+06	.9190E+05	.7352E+06	
Constants:	.34700	.27500	.40800	.29800
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.170	70.866	.9088E+04	2.717	139.5	110.5	139.5850	110.3967	.1051E-02	.7277E-03
.178	1.806	.1587E+05	2.898	139.5	110.0	139.6836	110.2171	.1119E-02	.1072E-02
.223	8.193	.1853E+05	2.928	140.0	110.0	139.7716	110.0133	.1193E-02	.9443E-03
.209	14.366	.1924E+05	2.929	140.0	110.0	139.8685	109.8187	.7842E-03	.7446E-03
.184	20.721	.1565E+05	2.802	140.0	109.5	139.9130	109.5821	.1014E-02	.7351E-03
.142	26.960	.1303E+05	2.873	140.0	109.0 *	139.9422	109.3479	.1525E-02	.5822E-02
.187	33.254	.1182E+05	2.976	140.0	109.0	139.9347	109.1216	.1408E-02	.1020E-02
.201	39.542	.1211E+05	2.956	140.0	109.0	139.9302	108.9266	.1412E-02	.1175E-02
.223	45.812	.1200E+05	2.917	140.0	109.0	139.9060	108.6870	.7442E-03	.4907E-03
.282	52.071	.1395E+05	2.796	140.0	108.5	139.8203	108.4882	.8684E-03	.4790E-03
.279	58.367	.2067E+05	3.027	140.0	108.0	139.7153	108.2821	.7271E-03	.9076E-03
.274	64.626	.1912E+05	2.952	139.5	108.0	139.5864	108.0893	.4458E-03	.1480E-02
.2?0	70.888	.2013E+05	2.927	139.5	108.0	139.4477	107.9302	.1207E-02	.5792E-03
.268	1.830	.2318E+05	3.004	139.0	108.0	139.3114	107.7379	.9095E-03	.1212E-02
.086	8.195	.2094E+05	2.810	139.0	107.5	139.1421	107.5864	.8175E-03	.1224E-02
.144	14.349	.2071E+05	2.805	139.0	107.5	138.9661	107.4610	.5248E-03	.1150E-02
.184	20.722	.2133E+05	3.029	139.0	107.0	138.7745	107.3441	.7296E-03	.1338E-02
.170	26.951	.1841E+05	2.953	138.5	107.0	138.5720	107.2423	.1297E-02	.1136E-02
.175	33.260	.1771E+05	2.955	138.5	107.0	138.3652	107.1764	.5508E-03	.2443E-03
.144	39.529	.1792E+05	2.964	138.0	107.0	138.1283	107.1194	.6490E-03	.5248E-03
.111	45.826	.1862E+05	2.971	138.0	107.0	137.8975	107.0903	.7360E-03	.1922E-02
.173	52.090	.1976E+05	3.005	138.0	107.0	137.6831	107.0906	.4114E-03	.9679E-03
.173	58.361	.1734E+05	2.932	137.5	107.0	137.5005	107.1471	.9458E-03	.3452E-03
.170	64.604	.1773E+05	2.982	137.0	107.0	137.2652	107.1804	.6480E-03	.1509E-02
.100	70.877	.1833E+05	2.962	137.0	107.0	137.0445	107.2677	.8582E-03	.2105E-02
.074	1.830	.2026E+05	2.834	137.0	107.5	136.8205	107.3977	.1669E-02	.1297E-02
.136	8.102	.1900E+05	2.770	136.5	107.5	136.6574	107.5034	.6472E-03	.1250E-02
.201	14.380	.1893E+05	2.821	136.5	107.5	136.4050	[illegible]	.8485E-03	.9194E-03
.344	20.726	.2042E+05	2.949	136.5	108.0	136.3342	107.7760	.2014E-03	.1124E-02
.321	26.969	.2219E+05	2.974	136.0	108.0	136.2022	107.9409	.5945E-03	.1451E-02
.271	33.247	.2114E+05	2.970	136.0	108.0	1?7.0404	108.1106	.2?07E-03	.1724E-02
.220	39.544	.1330E+05	2.95?	136.0	108.0	[illegible]	108.3?40	.3574E-03	.1047E-02
.?05	45.023	.1407E+05	2.703	136.0	108.5	[illegible]	[illegible]	[illegible]	.7624E-03
.113	[illegible]	[illegible]	2.419	136.0	[illegible]	[illegible]	108.7037	.1020E-02	[illegible]
.110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

.290	[illegible]	[illegible]E+05	2.9[illegible]	[illegible]	[illegible]	[illegible]	[illegible].12[illegible]	[illegible]E-0[illegible]	.10[illegible]
.316	70.870	.1753E+05	2.849	136.0	109.5	135.7372	109.2594	.1726E-02	.5199E 02
.330	1.044	.1665E+05	2.807	136.0	[illegible].5	[illegible].7582	109.6298	.4575E-03	.9276E-03
.318	8.197	.1865E+05	2.938	136.0	110.0	135.8193	109.8568	.1134E-02	.1110E 02
.275	14.383	.1807E+05	2.962	136.0	110.0	135.8614	110.0301	.1891E-02	.1190E 02
.2[illegible]	20.750	.1830E+05	2.947	136.0	110.0	[illegible].9465	110.2214	.1670E 02	.1600E 02
.223	26.977	.1040E+05	2.733	136.0	110.5	1[illegible].0640	110.3764	.1216E-02	.9451E 03
.260	33.251	.1148E+05	2.724	136.0	110.5	136.1917	110.5613	.1635E 02	.9529E 03
.251	39.535	.1262E+05	2.842	136.5	111.0	136.3434	110.7091	.9652E-03	.1021E 02
.220	45.902	.1434E+05	2.852	136.5	111.0	136.4972	110.8601	.6451E 03	.9677E-03
.192	52.100	.1627E+05	2.861	136.5	111.0	136.6721	110.9720	.1202E-02	.4962E 03
.206	58.362	.1848E+05	2.934	137.0	111.0	1[illegible]6.8504	111.0695	.1932E 0[illegible]	.6557E 03
.125	64.628	.1813E+05	2.919	137.0	111.0	137.0610	111.1681	.8275E-03	.6665E 03
.130	70.877	.1801E+05	2.938	137.0	111.0	137.2705	111.2490	.6847E-03	.1752E 02
.133	1.830	.1817E+05	2.903	137.5	111.0	137.4921	111.3296	.9675E-03	.1287E 02
.198	8.190	.2311E+05	2.969	138.0	111.5 *	137.7020	111.3457	.1658E-02	.2089E-01
.245	14.378	.2125E+05	2.896	138.0	111.5 *	137.9329	111.3294	.1075E 01	.2031E 01
.262	20.716	.1873E+05	2.910	138.0	111.0	138.1639	111.3246	.6664E-03	.9178E-03
.240	26.976	.1785E+05	2.909	138.5	111.0	138.3685	111.2833	.9205E-03	.9393E-03
.307	33.252	.1756E+05	2.886	138.5	111.0	138.5585	111.2005	.9157E-03	.1536E-02
.226	39.531	.1937E+05	2.921	139.0	111.0	138.7351	111.0810	.1023E-02	.1192E-02
.161	45.803	.1784E+05	2.885	139.0	111.0	138.9559	110.9778	.1621E-02	.1095E-02
.153	52.116	.1585E+05	2.870	139.0	111.0	139.1669	110.8631	.8889E-03	.1638E 02
.187	58.370	.1251E+05	2.862	139.5	111.0	139.3229	110.7020	.7429E-03	.1187E-02
.178	64.654	.1025E+05	2.719	139.5	110.5	139.4614	110.5591	.6348E-03	.4717E-03

ORIGINAL PAGE IS
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delta ri

	1	2	3	4	5	6
0	-.00028	-.00817	-.01516	.01236	.00256	.00602
1	-.00740	.01075	.03431	.01228	-.00180	-.01782
2	.04200	-.00960	-.00904	-.00954	-.00252	.01016
3	.01102	.02084	.03051	.0[illegible]464	.00926	.01722
4	.00554	.01539	-.01978	.01414	-.01317	-.022[illegible]
5	.00033	-.00701	-.01181	.0269[illegible]	-.00820	.0010[illegible]
6	-.00456	.00910	.00549	.0[illegible]457	.02027	.00528
7	.01094	-.00304	.01163	.00961	-.01639	.015[illegible]
8	.00702	.02510	.01772	-.00046	.01813	.02418
9	.00317	.04417	-.02620	.00460	-.01002	.00287

u= 137.8345 v0= 109.2260 r0= 2.10614419 std.dev.= .01703058

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	2	3	8	20	27	0

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delta ri

	1	2	3	4	5	6
0	.00037	-.00758	-.01464	.01202	.00295	.00514
1	-.00316	.01094	.03443	.01234	-.00180	-.01789
2	-.04212	-.00976	-.00925	-.00278	-.00279	.00906
3	.01071	.02051	.03019	.03471	.00895	.01497
4	.00528	-.01562	-.01997	-.01429	-.01328	.02070
5	-.00032	-.00773	-.01168	.02674	-.00793	.00142
6	-.00417	.00958	.00604	.02516	.02892	.00598
7	.01169	-.00224	.01247	-.00774	-.01549	-.01480
8	-.00507	.02606			.01908	.02511
9	-.00226	-.04329	-.02536	.00539	-.00927	-.00218

x0= 137.8346   y0= 109.2254   r0= 2.10582757   std.dev.= .01715546

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	2	1	8	17	28	2

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Disk 12-B Track data file TDATA11

	Coarse	Fine	Track
NORM	1.0	1.0	192.0
Integration delay:	.1160E+00	.4564E+00	.7974E+00
Thresholds:	.1838E+06	.9190E+05	.7352E+06

Constants:	.34700	.27500	.40900	.29800
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.279	1.809	.1280E+05	6.123	139.5	110.0	139.6419	110.2534	.3462E-02	.7505E-01
.304	8.159	.1337E+05	6.117	140.0	110.0	139.7500	110.0430	.2630E-02	.1721E-02
.285	14.374	.1340E+05	6.111	140.0	110.0	139.8531	109.8557	.2257E-02	.4924E-02
.422	20.720	.1329E+05	6.010	140.0	109.5	139.8901	109.5910	.2565E-02	.2069E-02
.408	26.955	.1320E+05	6.051	140.0	109.5	139.9214	109.3540	.2875E-02	.1661E-02
.361	33.248	.1302E+05	6.155	140.0	109.0	139.9104	109.1151	.2642E-02	.5193E-02
.358	39.530	.1296E+05	6.130	140.0	109.0	139.9145	108.9258	.2383E-02	.2161E-02
.332	45.804	.1292E+05	6.094	140.0	109.0	139.8942	108.6910	.1811E-02	.1977E-02
.380	52.089	.1304E+05	5.995	140.0	108.5	139.8035	108.4974	.2602E-02	.1307E-02
.313	58.354	.1317E+05	6.197	139.5	108.0	139.6684	108.3484	.4127E-02	.9251E-01
.355	64.625	.1282E+05	6.160	139.5	108.0	139.5435	108.1003	.1250E-02	.1613E-02
.428	70.880	.1292E+05	6.140	139.5	108.0	139.4087	107.9579	.1574E-02	.5039E-02
.445	1.799	.1327E+05	6.178	139.0	108.0	139.2670	107.7515	.1809E-02	.5992E-02
.296	8.183	.1296E+05	6.018	139.0	107.5	139.0844	107.6049	.3176E-02	.2130E-02
.462	14.377	.1293E+05	6.014	139.0	107.5	138.9064	107.4766	.2532E-02	.1089E-02
.303	20.718	.1309E+05	6.080	139.0	107.5	138.7041	107.3715	.1862E-02	.2190E-02
.377	26.954	.1102E+05	6.174	138.5	107.0	138.5368	107.2738	.2727E-02	.2137E-02
.302	33.237	.1095E+05	6.171	138.5	107.0	138.3264	107.2118	.1342E-02	.3262E-02
.234	39.540	.1083E+05	6.156	138.0	107.0	138.0978	107.1378	.1592E-02	.3022E-02
.215	45.817	.1083E+05	6.167	138.0	107.0	137.8616	107.1094	.3266E-02	.1919E-02
.130	52.095	.1062E+05	6.117	137.5	107.0	137.6579	107.1176	.8822E-03	.2338E-02
.142	58.358	.1061E+05	6.131	137.5	107.0	137.4660	107.1596	.5608E-03	.5447E-02
.111	64.635	.1060E+05	6.139	137.0	107.0	137.2204	107.1903	.273[illegible]-02	.3524E-02
.187	70.816	.1071E+05	6.137	137.0	107.0	136.9977	107.2804	.1540E-02	.2770E-02
.195	1.805	.1098E+05	6.047	137.0	107.5	136.7862	107.4075	.2490E-02	.5866E-02
.201	8.180	.1317E+05	5.980	136.5	107.5	136.6474	107.5128	.2087E-02	.1344E-02
.257	14.371	.1315E+05	6.031	136.5	107.5	136.4817	107.6366	.2226E-02	.1716E-02
.358	20.723	.1337E+05	6.162	136.5	108.0	136.3183	107.7872	.1417E-02	.1318E-02
.335	26.954	.1360E+05	6.142	136.0	108.0	136.1610	107.9363	.4005E-02	.1450E-02
.300	33.247	.1352E+05	6.141	136.0	108.0	136.0050	108.1068	.4069E-02	.3499E-02
.310	[illegible]	.1200E+05	6.026	136.0	108.5	[illegible]	[illegible]	[illegible]	[illegible]
.324	45.812	.1277E+05	[illegible]	136.0	108.5	[illegible]	[illegible]	[illegible]	[illegible]
.330	52.081	.1267E+05	6.061	136.0	109.0	[illegible]	[illegible]	[illegible]	[illegible]
.330	58.376	.9117E+04	7.070	135.5	109.0	[illegible]	[illegible]	[illegible]	[illegible]
.341	64.606	.8808E+04	7.000	135.5	109.0	[illegible]	[illegible]	[illegible]	[illegible]

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.3[illegible]	[illegible] 70.[illegible]	[illegible]	6.[illegible]	[illegible]	5 *	[illegible]	[illegible]	[illegible]	.00[illegible]02
.361	1.002	.1276E+05	5.985	136.0	109.5	135.7458	109.6369	.1572E-02	.0115E-02
.332	8.176	.1321E+05	6.101	136.0	110.0	135.8120	109.8744	.1725E 02	.4527E 02
.339	14.356	.1311E+05	6.113	136.0	110.0	135.8525	110.0409	.2297E 02	.3323E-02
.310	20.712	.1312E+05	6.099	136.0	110.0	135.9332	110.2302	.2419E-02	.7251 02
.237	26.969	.1268E+05	5.904	136.0	110.5	136.0487	110.3896	.2440E-02	.6761E 03
.265	33.276	.1270E+05	5.906	136.0	110.5	136.1776	110.5724	.0620E-03	.7665E-02
.262	39.540	.1262E+05	6.010	136.5	111.0	136.3312	110.7347	.1476E-02	.4385E-02
.307	45.825	.1270E+05	6.020	136.5	111.0	136.4780	110.8841	.2220E 02	.3669E-02
.307	52.060	.1283E+05	6.018	136.5	111.0	136.6456	110.9811	.2707E 02	.2236E 02
.321	58.379	.1053E+05	6.077	137.0	111.0	136.8263	111.0883	.3941E 02	.2305E-02
.268	64.634	.1050E+05	6.069	137.0	111.0	137.0310	111.1095	.1146E-02	.1995E-02
.282	70.877	.1044E+05	6.073	137.0	111.0	137.2480	111.2726	.2007E 02	.2917E-02
.306	1.815	.1057E+05	6.020	137.5	111.5 *	137.4590	111.3140	.9188E 02	.2146E-01
.330	8.107	.1045E+05	5.970	137.5	111.5	137.6759	111.3362	.1077E-02	.1696E-02
.375	14.377	.1058E+05	6.010	138.0	111.5	137.8994	111.3450	.2258E-02	.2380E-02
.290	20.748	.1049E+05	6.006	138.0	111.5	138.1479	111.3131	.2126E-02	.2871E 02
.313	26.955	.1041E+05	6.068	138.5	111.0	138.3392	111.3110	.2306E 02	.120 E-02
.327	33.273	.1042E+05	6.047	138.5	111.0	138.5227	111.2245	.1317E 02	.1739E-02
.332	39.510	.1035E+05	6.030	138.5	111.0	138.6987	111.1046	.1025E-02	.7665E 02
.335	45.774	.1239E+05	6.005	139.0	111.0	138.9121	110.9769	.201 E-02	.2589E-02
.304	52.096	.1229E+05	5.990	139.0	111.0	139.1216	110.8677	.2685E-02	.301 E-02
.321	58.373	.1194E+05	6.008	139.5	111.0	139.3143	110.7245	.3512E-02	.3487E 02
.285	64.624	.1188E+05	5.892	139.5	110.5	139.4431	110.5845	.4327E-02	.6326E-02
.327	70.870	.1173E+05	5.870	139.5	110.5	139.5597	110.4209	.1417E-02	.1487E-02

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delta 11

	1	2	3	4	5	6
0	-.01141	-.00736	.02685	.00252	.00775	-.00272
1	.02186	.04906	.02247	-.04294	-.02548	-.05300
2	-.01824	-.02698	-.02246	-.02678	-.00048	-.00261
3	.02751	.01806	.03570	.01747	.04269	.01221
4	.01072	.00557	-.00484	-.00412	.01616	.04576
5	.00715	.00566	-.02124	-.13270	-.14059	-.03538
6	.01560	.00923	.02746	.03372	.01426	.01717
7	.01166	.01399	.00170	-.00015	.00428	.01251
8	.00607	.00397	.00719	-.00045	.03581	.00728
9	.03793	-.04731	-.01474	.00765	.00916	.00457

n= 137.8205 .04= 102.2432 r05= 2.0370374 std.dev.= .0330471

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	3	5	6	12	11	23	0

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	delta r1					
	1	2	3	4	5	6
0		-.00738	.02685	.00,49	.00764	-.00246
1	.02149	.04930	.02169		-.02983	.05463
2	.02026	-.02938	-.0,523	-.02954	-.00398	-.00649
3	.02322	.03337	.02068	.01214	.03699	.02619
4	.00459	-.01210	-.01159	-.01106	.00907	.03854
5	.00015	.00147	-.02956		.14780	
6	.00870	.00254	.02097	.02747	.00826	.01147
7	.00730	.01897	-.00302	-.00451	.00032	.00895
8		.00116	.00476	-.00248	.03406	.00482
9	.03711	-.04010	-.01536	.00724	.00890	.004.2

r0= 137.8170   z0= 102.2421   r0= 2.09975147   std.dev.= .02943345

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	2	2	6	13	7	25	5

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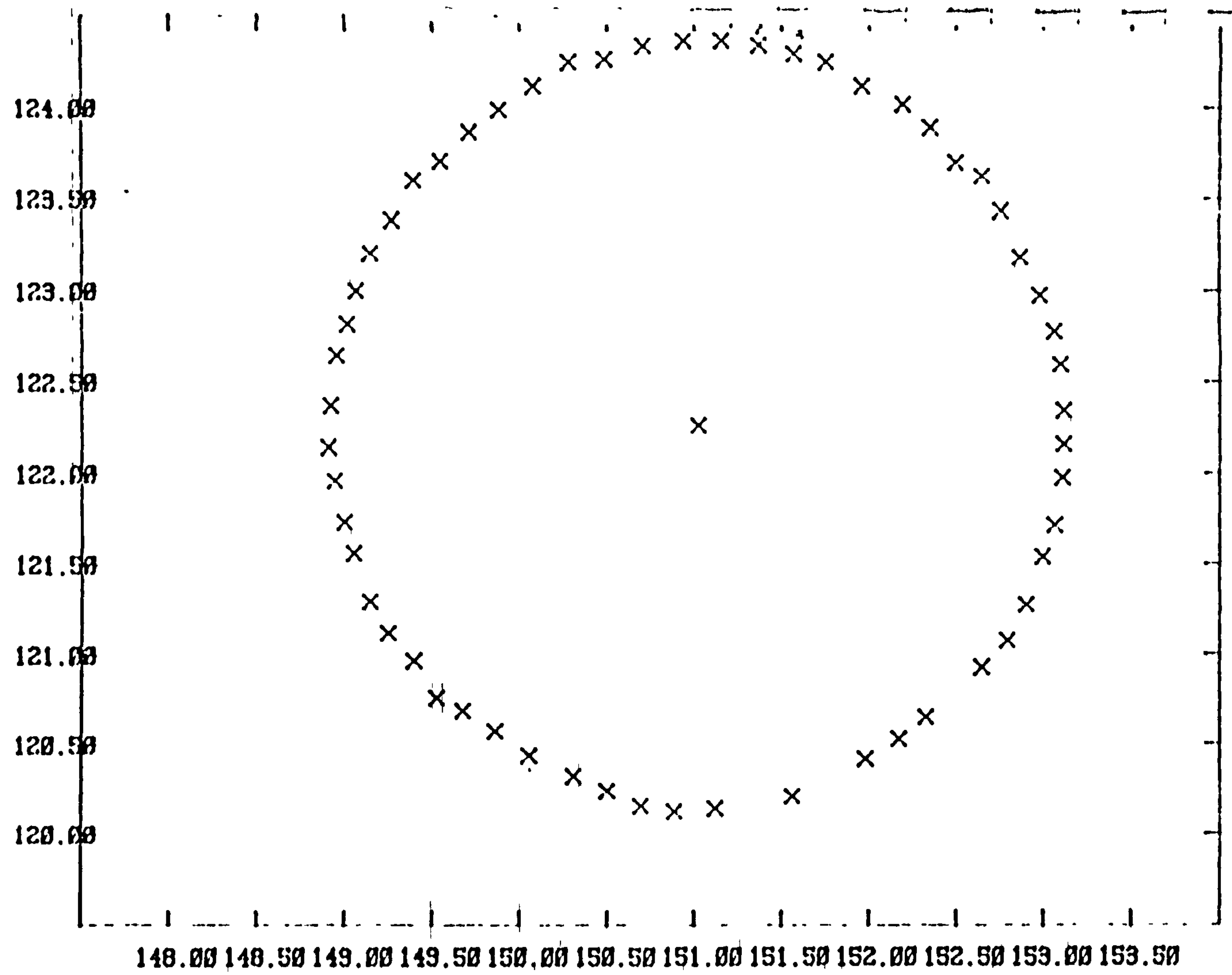

POSITION #2 S.D= 1.975 %

12-0-11 F2.8 -.5M 2 K=.298.255.367.302 100% 0°C

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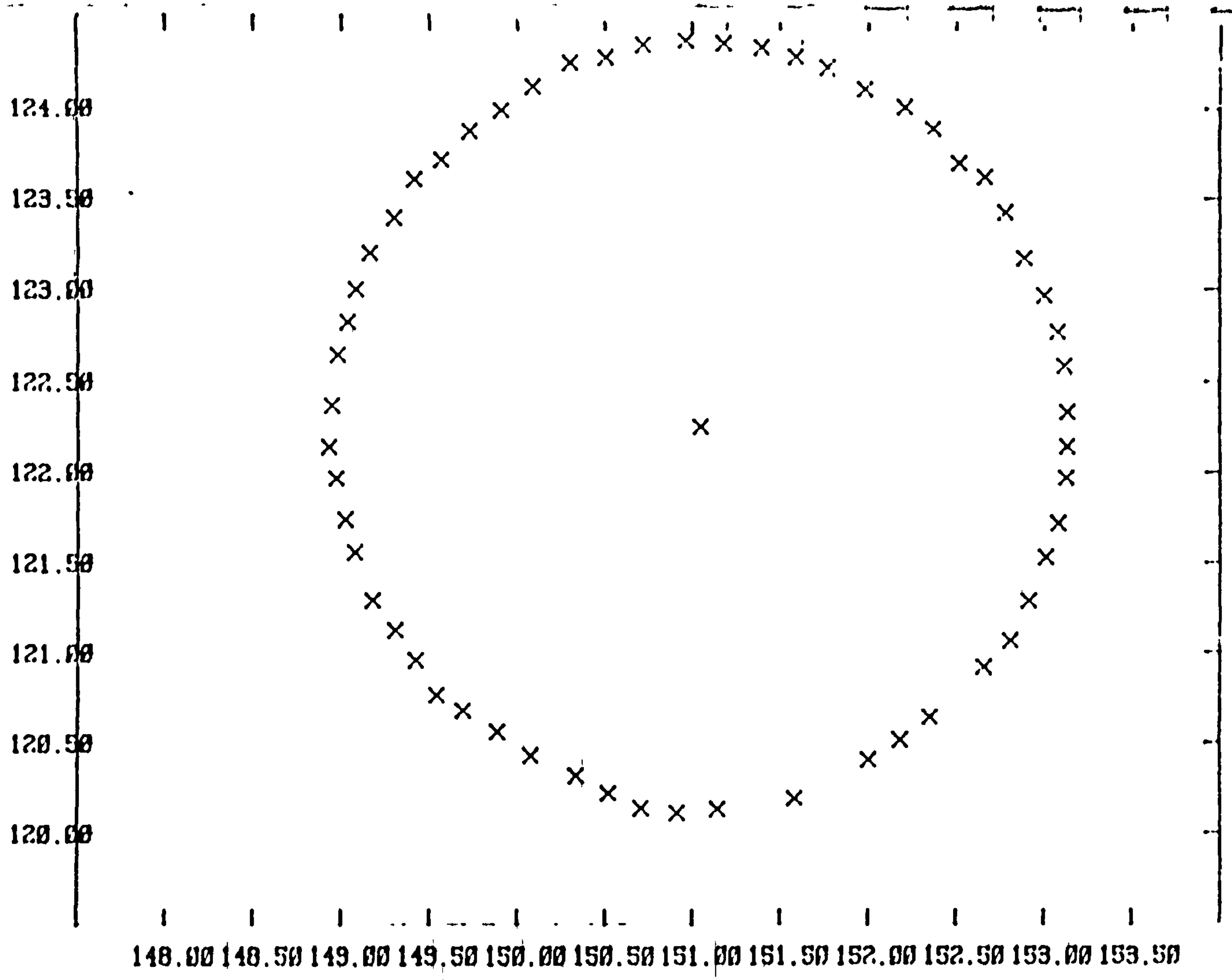

POSITION #2 S.D= 2.000%

12-0-10 F2.8 -.5M 2 K=.298.255.367.302 10% 0°C

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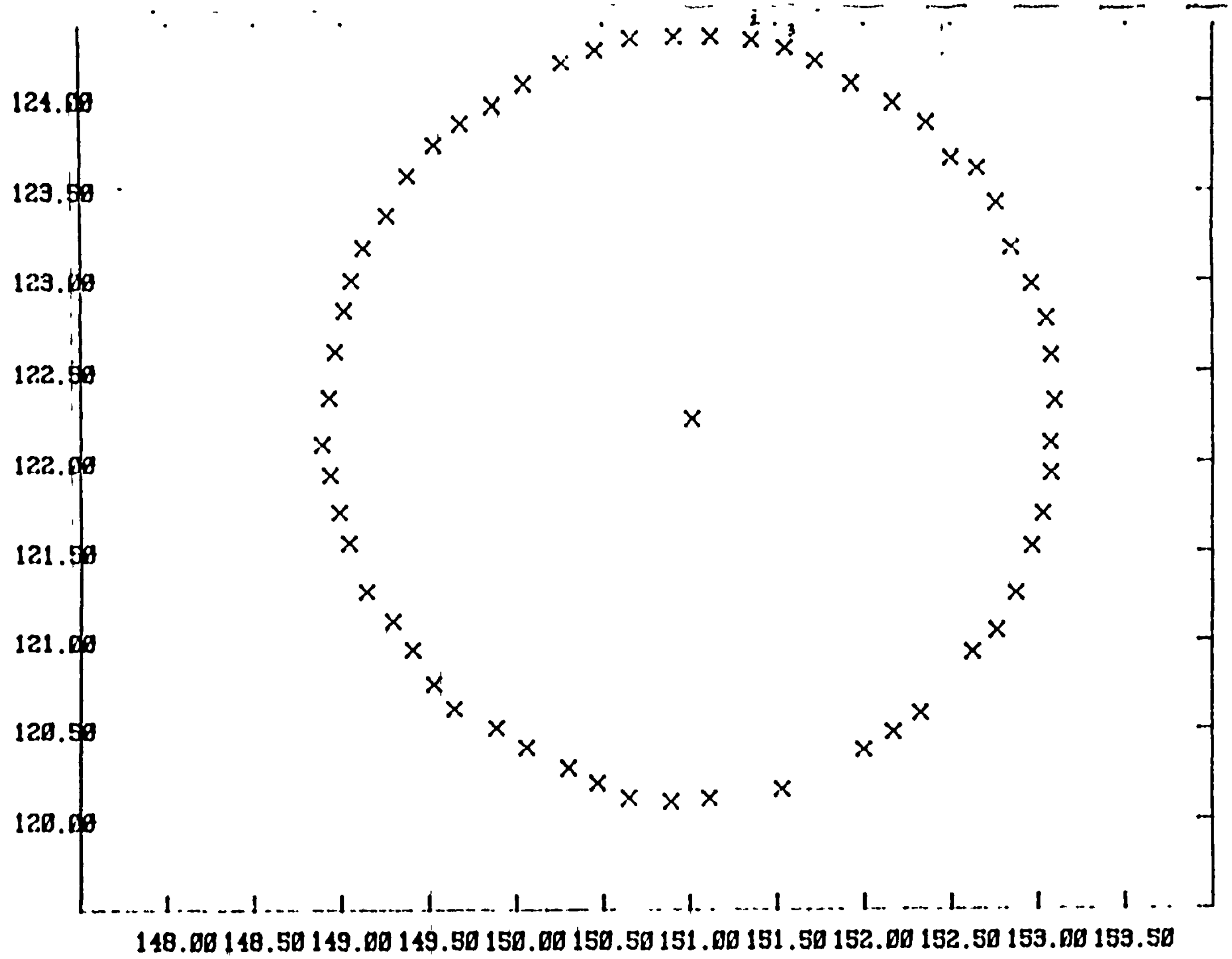

POSITION #2 S.D= 2.338%

27-A-00 F2.8 -.5M 2 K=.298.255.367.302 <1% 0° C

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Disk 12-A track data file [illegible]

	coarse	fine	track	
N[illegible]	1.0	1.0	16.0	
integration delays	.1170E+00	.4574E+00	.1044E-02	
thresholds	.3217E+06	.3190E+05	.7352E+06	
constants	.39500	.25500	.36700	.20,00
displacements	0.00000	0.00000	0.00000	0.00000

time	angle	dark current	star max.	reference X	reference Y		position X	position Y	standard deviation X	standard deviation Y
.175	14.376	.6220E+05	.979	151.0	124.5		151.1527	124.3626	.8770E-03	.7757E-03
.198	20.726	.5702E+05	1.006	151.5	124.5		151.[illegible]728	124.3404	.8160E-03	.1077E-02
.192	26.961	.5958E+05	1.020	151.5	124.5		151.5639	124.2907	.7943E-03	.8064E-03
.229	33.258	.1007E+06	1.032	152.0	124.0	*	151.7412	124.2449	.1216E-02	.2014E-02
.223	39.544	.1078E+06	1.033	152.0	124.0		151.9580	124.1198	.5715E-03	.6507E-03
.217	45.831	.1142E+06	1.013	152.0	124.0		15[illegible].1901	124.0234	.7101E-03	.5523E-03
.202	52.111	.9735E+05	1.049	152.5	124.0		152.3491	123.8902	.3987E-03	.7730E-03
.313	58.367	.1002E+06	1.050	152.5	124.0		152.4934	123.7031	.9527E-03	.7534E-03
.187	64.619	.9365E+05	.936	152.5	123.5		152.6425	123.6294	.4646E-03	.1296E-02
.105	70.859	.1085E+06	.946	153.0	123.5		152.7512	123.4370	.9417E-03	.4708E-03
.105	1.802	.2754E+05	1.030	153.0	123.0		152.8610	123.1867	.9165E-03	.8157E-03
.142	8.139	.8731E+05	1.012	153.0	123.0		15[illegible].9745	122.9760	.8935E-03	.9407E-03
.136	14.346	.7865E+05	1.004	153.0	123.0		15[illegible].0594	122.7804	.6680E-03	.6192E-03
.128	20.727	.4526E+05	.877	153.0	122.5		153.0930	122.5968	.5970E-03	.6167E-03
.116	26.946	.4334E+05	.901	153.0	122.5		153.1105	122.3411	.6562E-03	.5942E-03
.125	33.247	.9198E+05	1.032	153.0	122.0		153.1107	122.1571	.9248E-03	.4706E-03
.147	39.547	.8665E+05	1.050	153.0	122.0		153.1045	121.9757	.3920E-03	.1148E-02
.164	45.810	.9507E+05	1.038	153.0	122.0		153.0593	121.7176	.1350E-02	.5641E-03
.150	52.105	.8177E+05	.948	153.0	121.5		152.9863	121.5409	.4077E-03	.1004E-02
.187	58.367	.6746E+05	1.058	153.0	121.0	*	152.8934	121.2996	.1402E-02	.1152E-01
.158	64.625	.6012E+05	1.072	153.0	121.0		15[illegible].7847	121.0756	.4547E-03	.1114E-02
.170	70.852	.4838E+05	1.058	152.5	121.0		152.6389	120.9320	.1066E-02	.6516E-03
.147	1.813	.4547E+05	1.035	152.5	121.0		152.4811	120.7501	.3438E-03	.1199E-02
.142	8.148	.5332E+05	.952	152.5	120.5		152.3206	120.6526	.6813E-03	.9160E-03
.187	14.378	.6200E+05	.913	152.0	120.5		152.1646	120.5295	.1075E-02	.1035E-03
.206	20.714	.6247E+05	.974	152.0	120.5		151.9781	120.4214	.4342E-03	.1328E-02
.209	27.979	.1383E+06	1.145	152.0	120.0		151.7590	120.3451	.8141E-03	.9245E-01
.265	33.265	.8799E+05	1.078	151.5	120.0		151.5509	120.2135	.7068E-03	.6754E-03
.245	39.563	.9117E+05	1.059	151.5	120.0		151.3445	120.1784	.5670E-03	.7274E-03
.282	45.816	.1047E+06	1.043	151.0	120.0		151.1192	120.1457	.1349E-02	.5541E-01
.276	52.093	.1040E+06	1.055	151.0	120.0		150.8827	120.1259	.3756E-03	.1[illegible]
.290	58.361	.[illegible]	1.050	150.5	120.0		150.6092	120.1567	.7[illegible]	.1[illegible]
.30	64.700	.[illegible]	1.05[illegible]	150.5	1[illegible]		150.4[illegible]	120.[illegible]447	.7[illegible]-03	.1[illegible]
.1[illegible]	70.876	.61[illegible]	.9[illegible]	150.5	1[illegible]		150.[illegible]	1[illegible]	.40[illegible]	.1[illegible]
.217	1.816	.707[illegible]	.9[illegible]	150.0	120.[illegible]		150.[illegible]	120.4401	.7[illegible]	.[illegible]

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.164	8.1[illegible]	.7[illegible]E+05	[illegible]	1[illegible]	[illegible]	[illegible]	[illegible].576	[illegible]	[illegible]
.221	14.476	.6107E+05	.992	149.5	120.5	149.7729	120.6940	.9500E 03	.2474E 01
.21[illegible]	20.710	.4632E+05	1.091	149.5	121.0	149.5612	120.7876	.9044E 03	[illegible]
.147	27.385	.4220E+05	1.079	149.5	121.0	149.4939	120.5790	[illegible]	[illegible]
.179	33.279	.4291E+05	1.031	149.0	121.0 *	149.[illegible]507	121.1223	.1671E 01	.1125E 01
.237	39.526	.7034E+05	.936	149.0	121.5	149.1476	121.2992	.8085E 03	.5317E 03
.206	45.825	.7977E+05	.945	149.0	121.5	149.0514	121.5422	.9037E 03	.5027E 02
.223	52.090	.9433E+05	1.060	149.0	122.0	148.9980	121.7[illegible]	.7200E-03	.5042E 03
.234	58.367	.8752E+05	1.070	149.0	122.0	148.9424	121.9655	.1745E 02	.1447E 02
.243	64.624	.8551E+05	1.050	149.0	122.0	148.7030	122.1401	.5044E-03	.8208E-03
.195	70.800	.3728E+05	.909	149.0	122.5	148.9187	122.3727	.1421E-02	.4271E 03
.207	1.012	.4440E+05	.913	149.0	122.5	148.9527	122.6484	.6108E 03	.1117E 02
.209	8.160	.7275E+05	1.037	149.0	123.0	149.0120	122.8276	.1779E 02	.1403E 01
.178	14.474	.8395E+05	1.050	149.0	123.0	149.0617	123.0049	.8170E-03	[illegible]
.170	20.724	.8937E+05	1.038	149.0	123.0	149.1424	123.2125	.5405E 02	.5067E 03
.109	27.974	.9514E+05	.969	149.0	123.5	149.2754	123.3962	.9127E 03	.1077E 02
.217	33.286	.9252E+05	.957	149.5	123.5	149.2855	123.6089	.1155E-02	.6005E 03
.310	39.528	.1050E+06	1.022	149.5	124.0	149.5410	123.7150	.5631E 03	.1194E-02
.344	45.825	.1043E+06	1.026	149.5	124.0	149.7082	123.8720	.1477E-02	.1200E-02
.344	52.089	.1129E+06	1.053	150.0	124.0	149.6761	123.9956	.1727E-02	.8839E 03
.366	58.375	.1070E+06	1.053	150.0	124.0	150.0735	124.1198	.7486E-03	.7742E 03
.363	64.642	.8967E+05	1.052	150.5	124.0	150.2754	124.2481	.1164E-02	.6932E-03
.270	70.863	.5970E+05	1.029	150.5	124.5	150.4811	124.2652	.1195E 02	.6251E 03
.254	1.823	.5990E+05	.908	150.5	124.5	150.6984	124.3372	.9745E-03	.7027E 03
.189	8.103	.6102E+05	.993	151.0	124.5	150.9339	124.3645	.5751E+03	.6656E 03

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	1	2	3	4	5	6
0	[illegible]	.00908	.00363	.01315	-.01549	.01773
1	.01102	.03704	.02409	.00468	-.03600	.01790
2	.00750	.00327	-.00450	-.00301	.00783	.01477
3	.00153	.01050	.03101	-.00053	.00755	[illegible]
4	-.01814	-.01937	-.04013	.02424	.01494	.02501
5	.04713	.03781	-.00909	-.03155	-.03065	-.04568
6	.02413	.02377	-.01537	.00502	.01529	-.00402
7	[illegible]	.00544	.02670	.01079	.00942	.00704
8	.00046	.01025	-.00571	[illegible]	-.02098	[illegible]
9	-.01828	-.01047	[illegible]	[illegible]	.00363	[illegible]

x0= 151.0215 y0= 122.2634 r0= 2.09493661 std.dev.= .02000591

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	3	6	11	17	23	0

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delta ri

	1	2	3	4	5	6
0	.00892	.01039	.00409	.01755	-.01537	.01788
1	.01116	-.03601	.02484	-.00494	-.03710	-.01740
2	.00697	.00334	-.00526	-.00[illegible]76	.00689	.01361
3	.00277		.02969	-.00197	.00610	-.02700
4	.01776	-.02091		.01270	.01340	.02349
5	.04574	.03637	-.01048	-.03278	-.03188	.04681
6	-.02517	.02271	-.01623		.01274	-.00452
7	.00468	.00516	.02651	.01062	.00947	-.00890
8	.00068	.01056	-.00533	.02375	-.02047	-.01774
9	.01769	-.00985	.02602	-.02086	.00451	.00855

x0= 151.0219   y0= 122.2624   r0= 2.09540081   std.dev.= .01975182

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	2	5	13	16	21	3

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Disk 12-A Tract data file TDATA10 Position #2

	Coarse	Fine	Tract	
NDKOU	1.0	1.0	64.0	
Integration delay:	.1170E+00	.4564E+00	.1344E 02	
Thresholds:	.1030E+06	.9190E+05	.7352E+06	
Constants:	.23300	.25500	.36700	.30200
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.153	14.347	.1333E+05	2.761	151.0	124.5	151.1693	124.3484	.1777E-02	.1305E-02
.150	20.721	.1245E+05	2.803	151.5	124.5	151.3871	124.3271	.4648E-03	.2119E-02
.175	26.945	.1269E+05	2.809	151.5	124.5	151.5843	124.2771	.6725E-03	.6610E-03
.234	33.243	.2354E+05	2.813	152.0	124.0	151.7623	124.2181	.9636E-03	.2043E-02
.170	39.532	.2436E+05	2.809	152.0	124.0	151.9815	124.1006	.8958E-03	.9587E-03
.125	45.807	.2525E+05	2.795	152.0	124.0	152.2088	124.0081	.7872E-03	.1149E-02
.063	52.077	.2170E+05	2.843	152.5	124.0	152.3714	123.8881	.6553E-03	.1231E-02
.125	58.358	.2286E+05	2.836	152.5	124.0	152.5156	123.6961	.4631E-02	.1370E-02
.001	64.611	.1905E+05	2.722	152.5	123.5	152.6656	123.6217	.6339E-03	.8475E-03
.013	70.849	.2295E+05	2.742	153.0	123.5	152.7784	123.4258	.8947E-03	.3661E-03
.024	1.800	.2061E+05	2.805	153.0	123.0	152.8854	123.1671	.1594E 02	.1632E 02
.066	8.157	.1842E+05	2.783	153.0	123.0	152.9994	122.9662	.6350E-03	.7541E 03
.066	14.349	.1460E+05	2.773	153.0	123.0	153.0801	122.7711	.7602E-03	.8965E-03
-.018	20.730	.9792E+04	2.652	153.0	122.5	153.1143	122.5814	.9352E-03	.6901E-03
.021	26.964	.9490E+04	2.684	153.0	122.5	153.1305	122.3332	.1155E-02	.1601E-02
.066	33.205	.2073E+05	2.809	153.0	122.0	153.1311	122.1430	.7233E-03	.4464E-03
.060	39.531	.1991E+05	2.831	153.0	122.0	153.1268	121.9687	.1173E 02	.1363E 02
.077	45.819	.2213E+05	2.817	153.0	122.0	153.0812	121.7099	.5341E-03	.8270E 03
.027	52.083	.1762E+05	2.730	153.0	121.5	153.0071	121.5295	.4062E-03	.7782E 03
.128	58.366	.1498E+05	2.842	153.0	121.0	152.9110	121.2877	.8371E-03	.6564E-03
.100	64.626	.1344E+05	2.846	153.0	121.0	152.8051	121.0452	.6634E-03	.4302E 03
.161	70.859	.1117E+05	2.839	152.5	121.0	152.6535	120.9248	.8559E 03	.5525E 03
.156	1.823	.1027E+05	2.811	152.5	121.0	152.5039	120.7427	.5420E-03	.9193E 03
.167	8.152	.1264E+05	2.736	152.5	120.5	152.3454	120.6411	.9371E 03	.7828E-03
.128	14.364	.1316E+05	2.693	152.0	120.5	152.1799	120.5181	.8844E-03	.9537E-03
.139	20.737	.1315E+05	2.754	152.0	120.5	151.9979	120.4113	.8031E-03	.1331E 02
.156	26.750	.2959E+05	2.921	152.0	120.0	151.7767	120.3262	.9501E-02	.7801E-01
.133	33.256	.1955E+05	2.851	151.5	120.0	151.5769	120.1990	.6597E-03	.2656E-02
.133	39.545	.2007E+05	2.846	151.5	120.0	151.3682	120.1762	.5519E 03	.1186E 02
.147	45.819	.2471E+05	2.805	151.0	120.0	151.1366	120.1168	.1206E 02	.7129E 03
.212	52.117	.2337E+05	2.835	151.0	120.0	150.9044	120.1153	.1637E 02	.9651E 03
.133	58.370	.2014E+05	2.834	150.5	120.0	150.7011	120.1430	.9227E 03	.6594E 03
.125	64.637	[illegible]	2.844	150.5	120.0	[illegible]	[illegible]	[illegible]	[illegible]
.105	70.022	[illegible]	2.704	150.5	120.5	[illegible]	[illegible]	[illegible]	[illegible]
.006	1.107	[illegible]	2.780	150.0	120.5	[illegible]	[illegible]	[illegible]	[illegible]

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.045	[illegible]	[illegible]	2.71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.041	14.405	.1320E+05	2.777	149.5	120.5	149.6064	120.6837	.3992E-03	.9347E-03
.052	20.743	.1052E+05	2.868	149.5	121.0	149.5353	120.7663	.7934E-03	.1261E-02
.080	26.971	.9678E+04	2.851	149.5	121.0	149.4150	120.9611	.1690E-02	.1645E-02
.112	33.273	.9444E+04	2.815	149.5	121.0	149.3013	121.1255	.4064E-03	.1110E 0[illegible]
.077	39.557	.1634E+05	2.762	149.0	121.5	149.1718	121.2929	.1844E 01	.1662E-01
.030	45.038	.172[illegible]E+05	2.725	149.0	121.5	149.0707	121.5563	.410[illegible]E 03	.[illegible]E 01
.116	52.110	.2104E+05	2.045	149.0	122.0	149.0194	121.7[illegible]	.6790E 03	.2709E 02
.122	53.370	.200[illegible]E+05	2.052	149.0	122.0	148.9677	121.9652	.2174E 0[illegible]	.1177E 0[illegible]
.052	64.743	.1908E+05	2.831	149.0	122.0	148.9[illegible]57	122.1433	.[illegible]E 02	.1715E 02
.013	70.081	.0401E+04	2.691	149.0	122.5	148.9410	122.3703	.0566E 03	.1015E 02
.034	1.827	.950[illegible]E+04	2.69[illegible]	149.0	122.5	148.9739	122.6407	.8.67E-03	.7094E 03
.041	8.106	.1537E+05	2.807	149.0	123.0	149.0422	122.8262	.1539E 02	.7837E-03
.052	14.378	.1762E+05	2.817	149.0	123.0	149.0795	123.0010	.1349E-02	.5981E-03
.041	20.721	.1902E+05	2.809	149.0	123.0	149.1568	123.1997	.8075E-03	.1765E 02
.060	26.977	.1929E+05	2.753	149.5	123.5	149.2935	123.3991	.1629E-02	.0623E-03
.015	33.278	.1951E+05	2.743	149.5	123.5	149.4106	123.6075	.4556E-03	.4617E-03
.116	39.543	.2341E+05	2.812	149.5	124.0	149.5619	123.7186	.9940E-03	.9159E-03
.036	45.812	.2276E+05	2.822	149.5	124.0	149.7247	123.8745	.1224E 02	.2007E 02
.069	52.109	.2470E+05	2.837	150.0	124.0	149.9020	123.9919	.9830E 03	.0684E 03
.170	58.033	.2352E+05	2.830	150.0	124.0	150.0069	124.1161	.1295E 02	.2314E-02
.122	64.640	.1904E+05	2.037	150.5	124.0	150.2978	124.2448	.5079E-03	.2148E 02
.049	70.000	.1254E+05	2.813	150.5	124.5	150.4966	124.2729	.1990E 02	.1001E 0[illegible]
.015	1.826	.1293E+05	2.778	150.5	124.5	150.7113	124.3421	.5375E-03	.1357E-02
.046	8.163	.1314E+05	2.771	151.0	124.5	150.9558	124.3654	.1645E 02	.8891E 03

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	1	2	3	4	5	6
0	.00116	.00454	-.00252	-.00497	.02509	.00984
1	.00779	.03481	.02634	-.00164	-.03916	-.01125
2	.00663	.00203	-.00575	-.00356	.00911	.01540
3	.00084	.00889	.03143	-.00593	.00755	.02093
4	-.01896	-.01860	-.03145	.02905	.01876	[illegible]
5	.04072	.04392	.00123	-.03816	.03171	.04101
6	.02028	.02259	.01674	-.02055	.00762	.00414
7	.00747	-.00019	.02356	.00139	.00796	.00643
8	.00366	.01274	.00642	.02320	-.01445	.00848
9	.01839	-.00411	.02832	-.00577	.01703	.01612

x0= 151.0420 y0= 122.2553 r0= 2.09572840 std.dev.= .02011792

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	3	6	11	11	29	0

delta ri

	1	2	3	4	5	6
0	.00159	.00430	-.00224	.00477	.02500	[illegible]
1	.00277	.01505	.02602	.00208	.04974	.01124
2	.00593	.00114	-.00676	-.00465	.00795	[illegible]
3	-.00215	.00251	.03000	-.00739	.00645	.02248
4	-.02047	-.01010		.02761	.01738	.02455
5	.04745	.04272	.00010	-.03921	-.04263	.04772
6	[illegible]	.02178	.01724	-.01094		.00410
7	-.00752	-.00013	.02370	.00863	.00830	-.00702
8	.00413	.01327	-.00584	.02382	-.01381	-.00772
9	-.01773	-.00347	.02894	-.00517	.01758	.01761

x0= 151.0426 y0= 122.2545 r0= 2.09615254 std.dev.= .02000283

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	3	5	13	9	28	2

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Disk 27-A Track data file TDA100[illegible]

	Coarse	Fine	Track
NDROI	1.0	1.0	192.0
Integration delay:	.1120E+00	.4564E+00	.7974E+00
Thresholds:	.1838E+06	.9190E+05	.7352E+06

Constants:	.29800	.25500	.36700	.30200
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.142	14.361	.1221E+05	6.010	151.0	124.5	151.1218	124.3611	.7980E-03	.9823E-03
.198	20.716	.1211E+05	6.061	151.5	124.5	151.3601	124.3410	.1921E-02	.2093E-02
.170	26.950	.1212E+05	6.072	151.5	124.5	151.5523	124.2983	.1491E-02	.1659E-02
.195	33.267	.1275E+05	6.086	151.5	124.0	151.7236	124.2198	.1540E-02	.9620E-02
.240	39.527	.1305E+05	6.071	152.0	124.0	151.9319	124.0090	.1920E-02	.1903E-02
.107	45.787	.1390E+05	6.045	152.0	124.0	152.1700	123.9096	.1006E-02	.2564E-02
.192	52.079	.1360E+05	6.106	152.5	124.0	152.3599	123.8814	.1057E-02	.4912E-02
.226	58.370	.1368E+05	6.123	152.5	124.0	152.5025	123.6863	.1068E-02	.2335E-02
.102	64.603	.1342E+05	6.015	152.5	123.5	152.6537	123.6201	.2553E-02	.3467E-02
.024	70.863	.1246E+05	6.014	152.5	123.5 *	152.7548	123.4381	.1361E-01	.5123E-02
-.001	1.802	.1087E+05	6.037	153.0	123.0	152.8478	123.1858	.1700E-02	.9546E-03
.013	8.139	.1080E+05	6.010	153.0	123.0	152.9635	122.9804	.2619E-02	.253[illegible] 02
.032	14.354	.1056E+05	6.009	153.0	123.0	153.0495	122.7910	.8703E-03	.3527E-02
.074	20.720	.1031E+05	5.925	153.0	122.5	153.0795	122.5931	.5874E-02	.1329E-01
[illegible]	26.954	.1014E+05	5.930	153.0	122.5	153.0977	122.3360	.1000E-02	.27[illegible] 02
.021	33.263	.1077E+05	6.029	153.0	122.0	153.0718	122.1117	.2730E-02	.25[illegible]-02
.102	39.524	.1077E+05	6.050	153.0	122.0	153.0744	121.9379	.7514E-02	.2792E-02
.091	45.818	.1090E+05	6.055	153.0	122.0 *	153.0275	121.6985	.4043E-02	.4208E-01
.080	52.098	.1062E+05	5.970	153.0	121.5	152.9627	121.5321	.2120E-02	.2220E-02
.074	58.373	.1047E+05	6.053	153.0	121.0 *	152.8676	121.2799	.5939E-02	.8051E-02
.083	64.632	.1040E+05	6.053	153.0	121.0	152.7590	121.0579	.7311E-03	.2297E-02
.125	70.848	.1264E+05	6.051	152.5	121.0	152.6200	120.9380	.2431E-02	.3313E-02
.091	1.720	.1259E+05	6.033	152.5	121.0	152.4698	120.7584	.1462E-02	.2972E-02
.024	8.141	.1201E+05	5.934	152.5	120.5	152.3167	120.5929	.230[illegible] 02	.161[illegible]-02
.031	14.345	.1205E+05	5.868	152.0	120.5	152.1631	120.4047	.213[illegible]-02	.1409E-02
.111	20.719	.1286E+05	5.923	152.0	120.5	151.9939	120.3047	.1112E-02	.1834E-02
.136	26.940	.1319E+05	6.086	151.5	120.0 *	151.7216	120.2740	.2424E-01	.6782E-01
.158	33.258	.1268E+05	6.023	151.5	120.0	151.5220	120.1734	.3005E-02	.2577E-02
.220	39.504	.1273E+05	6.015	151.5	120.0	151.3263	120.1457	.1848E-02	.1643E-02
.270	45.772	.1320E+05	5.906	151.0	120.0	151.1064	120.1229	[illegible]	[illegible]
.215	52.072	.1127E+05	5.976	151.0	120.0	150.[illegible]	120.1057	.1054E-02	.2104E-02
.251	58.[illegible]	.1025E+05	6.017	150.5	120.0	150.6452	120.1250	[illegible]	.8171E-02
.206	64.722	.1014E+05	6.034	150.5	120.0	150.4615	120.2000	[illegible]	[illegible]
.175	70.[illegible]	.1040E+05	5.947	150.5	120.5 *	150.2971	120.3070	[illegible]	[illegible]
.116	1.700	.1020E+05	5.[illegible]	150.0	120.5	150.[illegible]	120.4017	[illegible]	[illegible]

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.12	0.	[illegible]	5.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.105	14.351	.1039E+05	5.945	149.5	120.5	149.6411	120.6210	.1903E 02	.1678E 02
.144	20.711	.1030E+05	6.071	149.5	121.0	149.5240	120.7599	.1472E 02	.4959E 02
.047	27.947	.1027E+05	6.040	149.5	121.0	149.4016	120.9540	.1721E 02	.2147E 02
.107	33.242	.1024E+05	6.024	149.5	121.0	149.2905	121.1129	.5791E 03	[illegible]
.094	37.403	.1070E+05	6.007	149.0	121.5	149.1364	121.2793	.2979E 01	.3524E 01
.029	45.817	.1059E+05	5.941	149.0	121.5	149.0345	121.5536	[illegible]	[illegible]
.063	52.044	.1106E+05	6.058	149.0	122.0	148.9852	121.7152	.5724E-02	.4616E-01
.102	58.350	.1102E+05	6.095	149.0	122.0	148.9304	121.9324	.2587E 02	[illegible]
.032	64.602	.1096E+05	6.034	149.0	122.0	148.8942	122.1081	[illegible]	[illegible]
.055	70.877	.9837E+04	5.895	149.0	122.5	148.9266	122.2571	.2700E 02	.1574E 02
.069	1.801	.9809E+04	5.885	149.0	122.5	148.9606	122.6163	.2505E-02	.2156E-02
.100	8.148	.1026E+05	5.979	149.0	123.0	149.0105	122.8387	.2599E-02	.2641E 02
.027	14.371	.1040E+05	5.989	149.0	123.0	149.0507	123.0043	.1379E-02	.2444E 02
.083	20.703	.1049E+05	5.989	149.0	123.0	149.1211	123.1893	.1710E-02	.2711E-02
.036	26.952	.1082E+05	5.999	149.5	123.5 *	149.2729	123.3726	.1421E 01	.1406E 01
.114	33.250	.1042E+05	5.970	149.5	123.5	149.3770	123.5872	.1500E 02	[illegible]
.164	39.524	.1033E+05	6.024	149.5	124.0 *	149.5278	123.7489	.2064E 02	.3709E 01
.243	45.774	.1073E+05	5.984	149.5	124.0	149.6706	123.8807	.2290E-02	.2307E 02
.237	52.044	.1098E+05	5.993	150.0	124.0	149.8647	123.9769	.1601E 02	.1017E 02
.254	58.361	.1090E+05	5.990	150.0	124.0	150.0449	124.0866	.3974E-02	.2209E 02
.245	64.700	.1081E+05	6.025	150.5	124.0 *	150.2659	124.2090	.9564E 02	[illegible]
.260	70.095	.1021E+05	6.012	150.5	124.5	150.4551	124.2014	.2125E-02	[illegible]
.170	1.798	.1017E+05	5.972	150.5	124.5	150.6616	124.3489	.1171F-02	.1925F-02
.161	8.138	.1250E+05	5.934	151.0	124.5	150.9122	124.3607	.1965E-02	.1295F-02

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delta ri

	1	2	3	4	5	6
0	.010[illegible]	.0[illegible]414	.0[illegible]04	.00[illegible]	.01[illegible]	.00[illegible]
1	.0[illegible]0[illegible]0	.0[illegible]580	.04760	.01324	-.04577	.01299
2	.01115	-.00155	-.01027	-.04300	-.01264	.00[illegible]
3	.0[illegible]090	-.00716	.01436	-.02[illegible]	.01577	.00720
4	.00519	.00548	-.00350	.03539	.02403	.02[illegible]
5	.04410	.05226	.00974	-.0[illegible]86	-.02282	.03171
6	.02490	.00243	.03758	-.04060	.00[illegible]0	-.00655
7	-.00394	.00332	.03045	-.01350	-.01723	-.01428
8	.00107	.01152	-.02935	.01374	.01105	.00845
9	-.02427	-.02153	-.00053	.00987	.0317[illegible]	.01710

u= 151.0101   v0= 122.2460   r0= 2.09389357   std.dev.= .02257377

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	3	9	13	15	19	0

delta ri

	1	2	3	4	5	6
0	.01859	.02462	.02339	-.00042	-.03846	.00499
1	.02130	-.02511	.04827		-.03522	-.01254
2	.01150		-.01018	-.03386	-.01283	
3	.02140	-.00680	.01343	-.02671	-.01705	.00574
4	.00358	.00321		.03326	.02177	.02293
5	.04160	.04275	.00707		-.02561	-.03452
6	.02208	-.000[illegible]8	-.04035	-.04333		-.00910
7		.00098	.02821	-.01558	-.01912	-.01600
8	.00051	.01010		.01231		.00777
9	.02478	-.02187	-.00069	.00285	.03186	.01737

x0= 151.0020 y0= 122.2446 r0= 2.10095263 std dev.= .02337596

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	5	6	13	13	14	9

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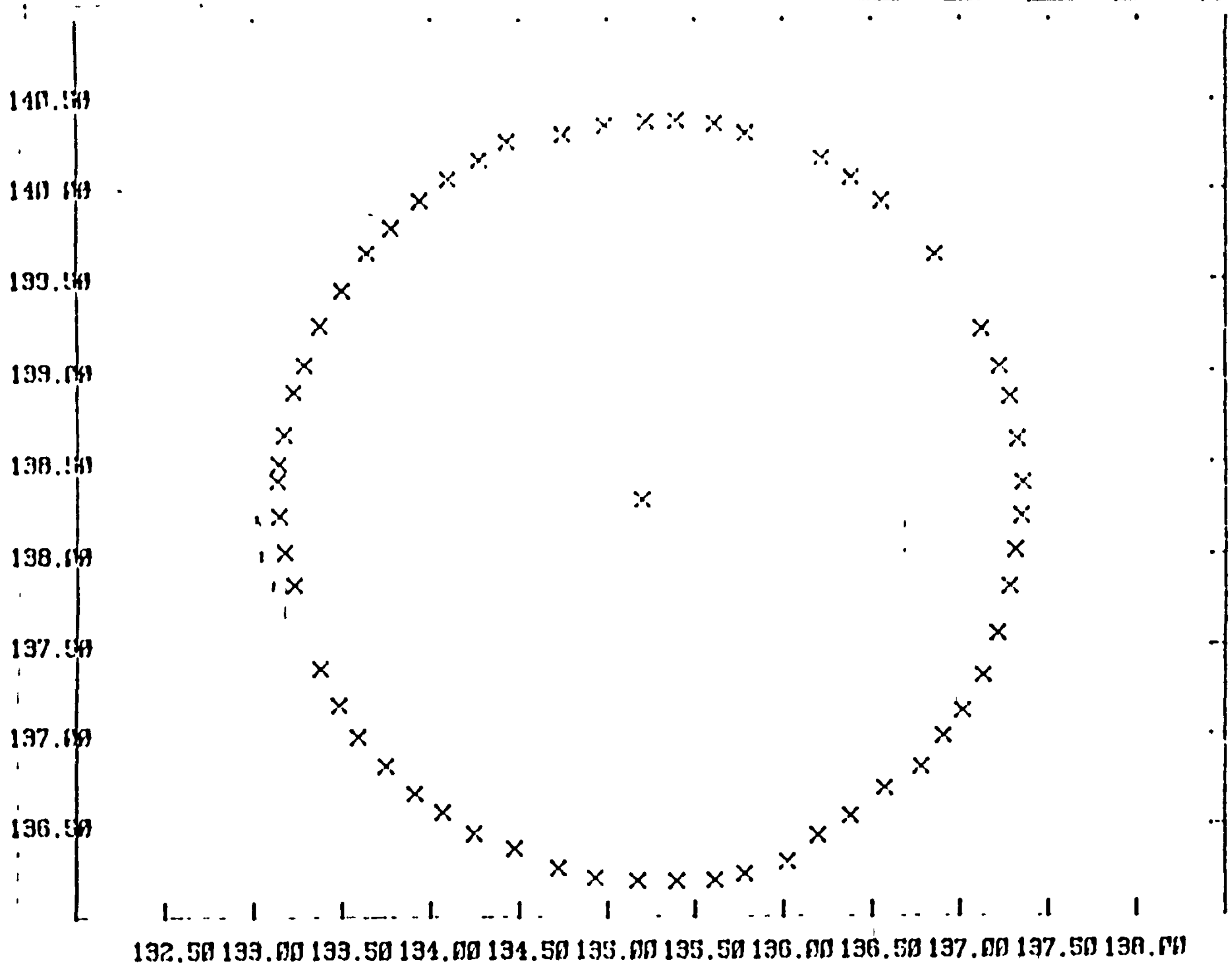

POSITION #3 S.D= [illegible] %

27-0-08 F2.8 +.9M 2 I=.337,.287,.378,.28 100% 0°C

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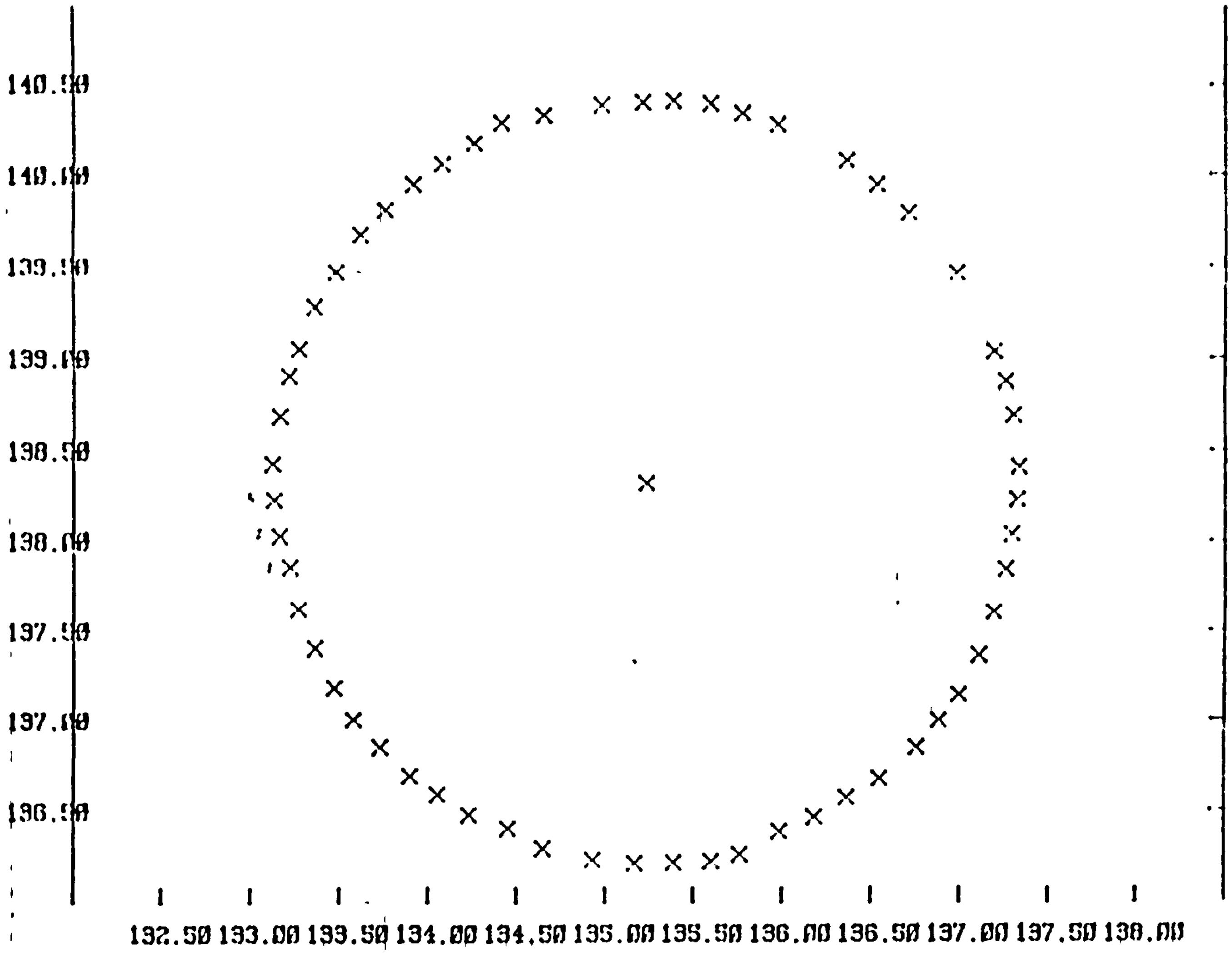

POSITION #3 S.D= 1.336%

27-0-07 F2.8 +.9M 2 L..337.087.378.28 10% 0'C

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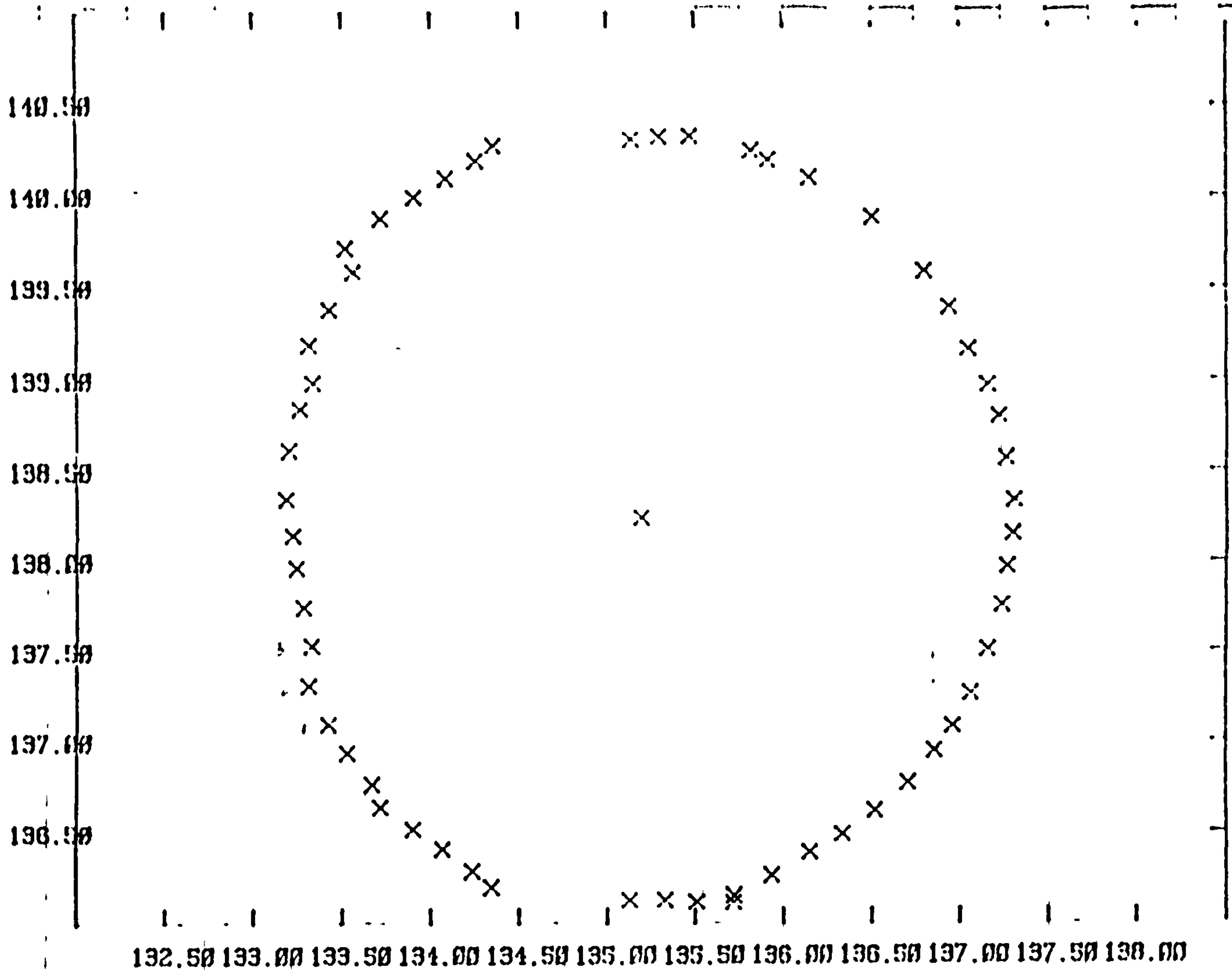

POSITION #3 S.D= 4.912%

27-A-Ø9 F2.8 +.9M 2 K=.337.287.378.28 <1% Ø°C

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Dow 27-A

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Disk 27-A Position #3

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C-2

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delta

[illegible]

std.dev.

HISTOGRAM DEVIATION

.04 .01 .0 .01 0.00 bad points

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	.01447	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] DEVIATION

[illegible] bad points

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[illegible] DEVIATION = [illegible]

[illegible]	.05	.04	.03	[illegible]	.01	0.00	bad points
	14	[illegible]	[illegible]	4	[illegible]	14	[illegible]

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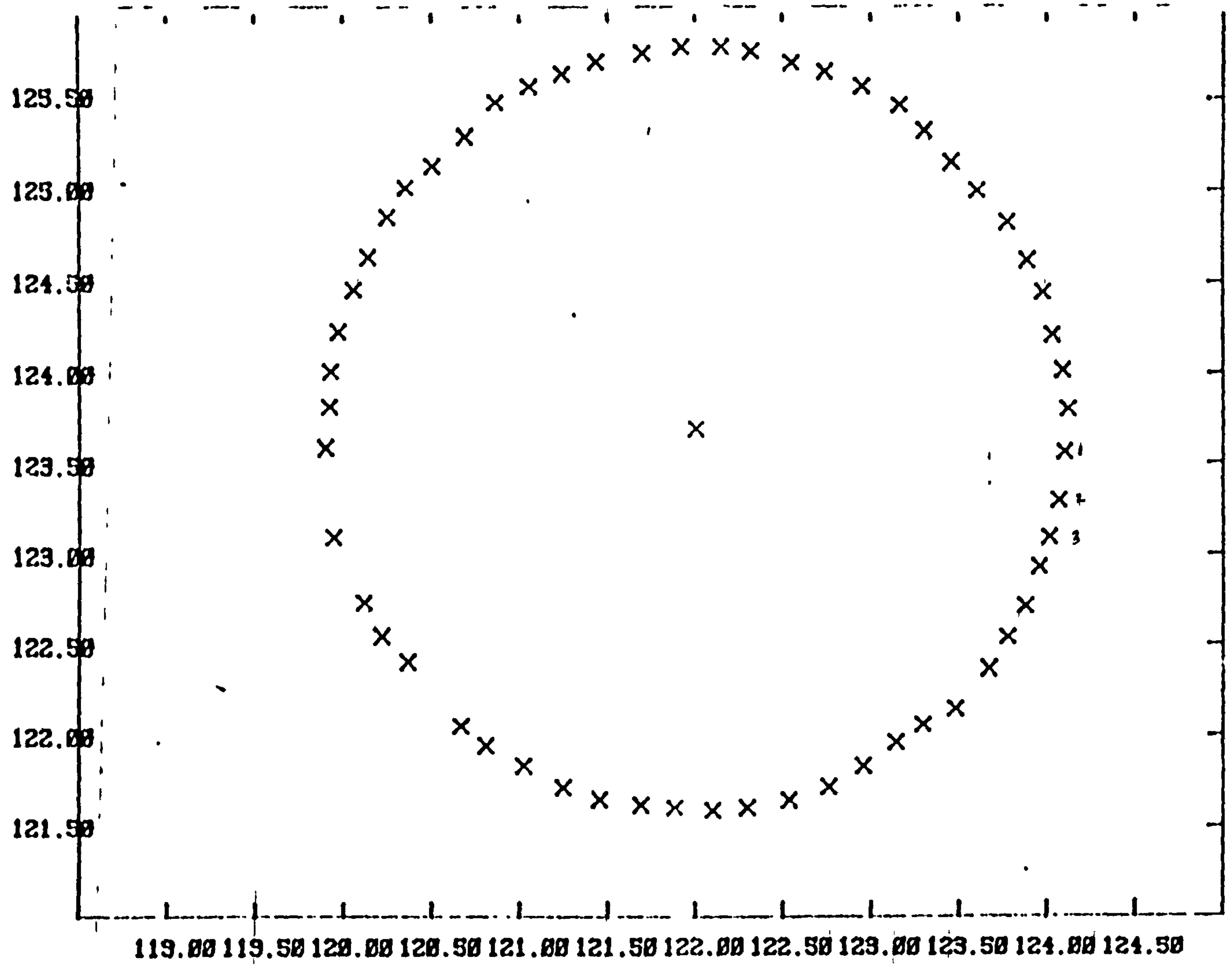

POSITION #4 S.D= 1.492 %

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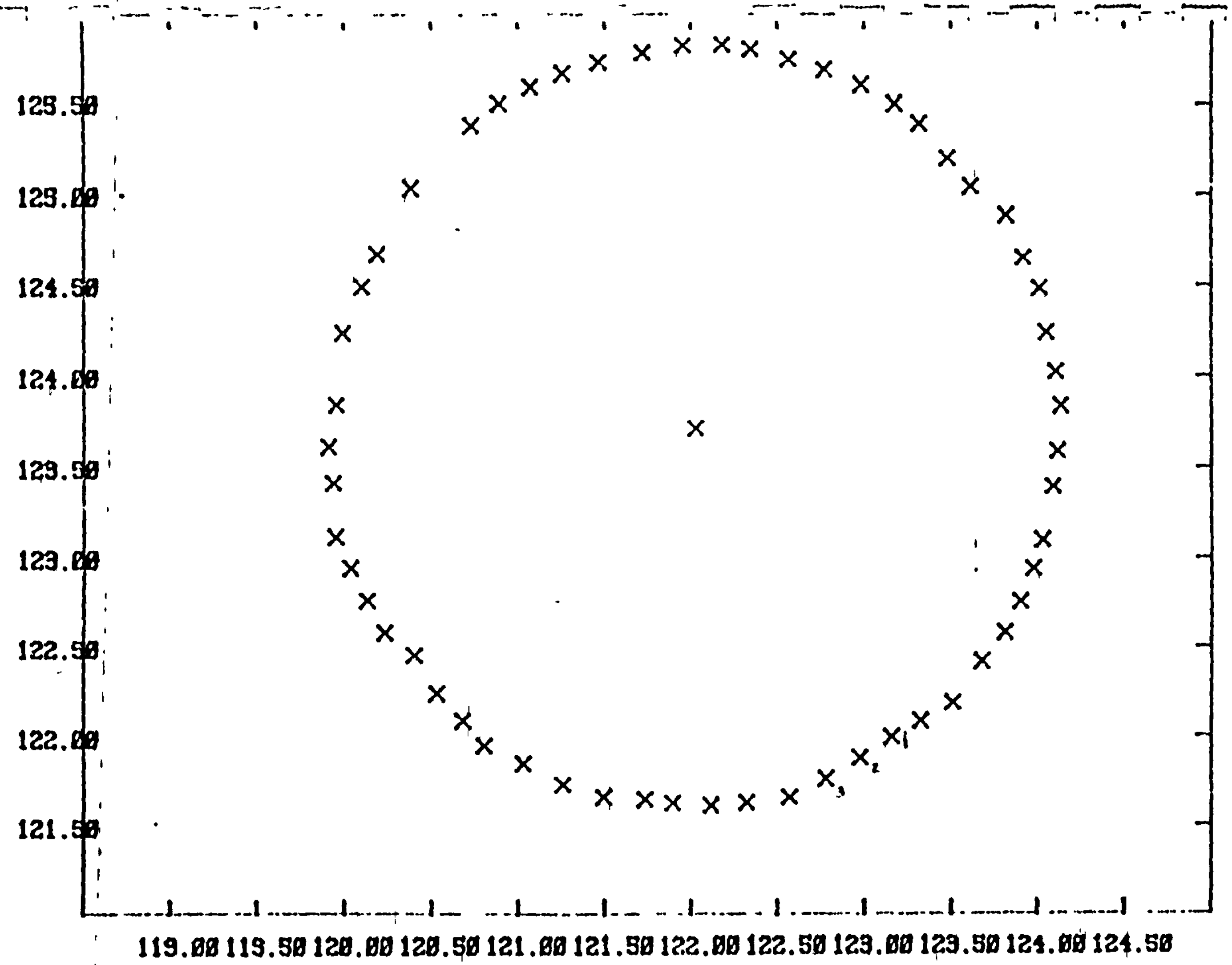
TR81-04

29-A-03 F2.8 +.8M 2 K=.33.294.37.236 10% 0°C



POSITION #4 S.D= 2.170%

29-A-04 F2.8 +.8M 2 K=.33.294.37.236 <1% Ø°C

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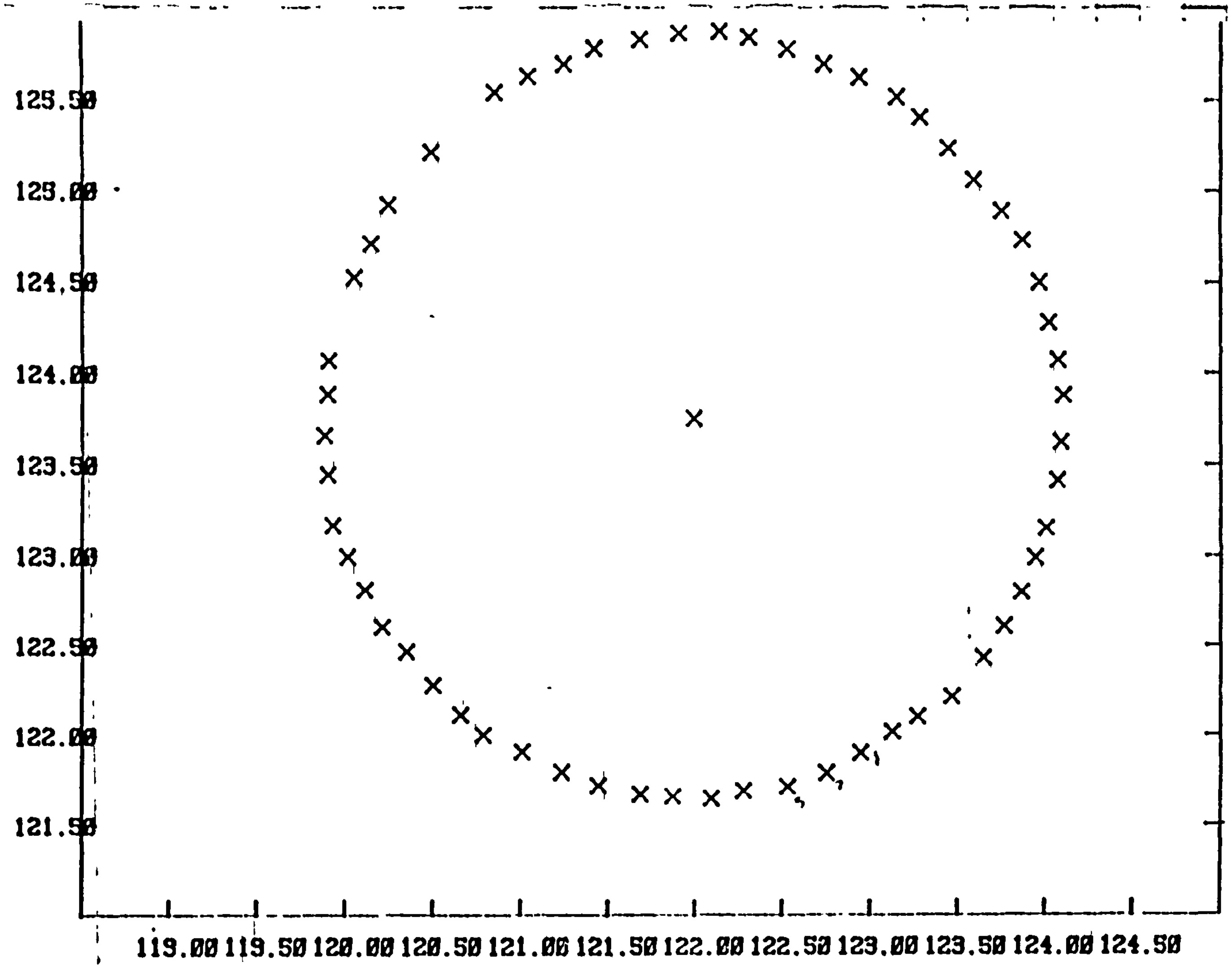
TR81-04



POSITION #4 S.D= 1.368 %

29-A-Ø6 F2.8 +.8M 2 K=.33.294.37.236 1ØØ% 1Ø°C

Disk 29-A Track data file TDATA00 Position #4

	Coarse	Fine	Track	
NR[illegible]	1.0	1.0	16.0	
Integration delay:	.1170E+00	.4564E+00	.1344E+02	
Thresholds:	.1838E+06	.9190E+05	.2352E+06	
Constants:	.33000	.29400	.37000	.23600
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.440	8.201	.7181E+05	1.136	123.5	122.0	123.3125	122.0817	.1871E-02	.8147E-03
.498	14.412	.7973E+05	1.162	123.0	122.0	123.1582	121.9930	.1843E-02	.1340E-02
.462	20.766	.7954E+05	1.151	123.0	122.0	122.9741	121.8716	.1105E-02	.1444E-02
.490	27.014	.8405E+05	1.136	123.0	122.0	122.7840	121.7637	.2036E-02	.2757E-02
.448	33.292	.7372E+05	1.063	122.5	122.0	122.5647	121.6901	.2089E-02	.1492E-02
.467	39.597	.8319E+05	1.006	122.5	121.5	122.3149	121.6372	.1041E-02	.9242E-03
.464	45.846	.7293E+05	1.041	122.0	121.5	122.1199	121.6248	.1655E-02	.8341E-03
.4[illegible]	52.132	.8192E+05	1.063	122.0	121.5	121.9011	121.6347	.1720E-02	.1269E-02
.495	58.427	.8860E+05	1.109	122.0	121.5	121.6955	121.6568	.2162E-02	.1058E-02
.476	64.668	.7167E+05	1.112	121.5	122.0	121.4774	121.7038	.5979E-03	.1943E-02
.487	70.902	.8339E+05	1.189	121.0	122.0	121.2563	121.7662	.2537E-02	.3554E-02
.470	1.859	.8067E+05	1.161	121.0	122.0	121.0406	121.8792	.7430E-03	.1152E-02
.448	8.237	.7986E+05	1.141	121.0	122.0	120.8242	121.9841	.1446E-02	.1156E-02
.467	14.402	.6960E+05	1.093	120.5	122.0	120.6877	122.0906	.7541E-03	.1120E-02
.504	20.777	.7329E+05	1.105	120.5	122.0	120.5319	122.2397	.2530E-02	.2620E-02
.439	26.990	.4836E+05	.910	120.5	122.5	120.3805	122.4439	.3920E-02	.2564E-02
.467	33.303	.5409E+05	.954	120.0	122.5	120.2359	122.5790	.1647E-02	.1497E-02
.425	39.562	.6562E+05	1.110	120.0	123.0	120.1337	122.7840	.1570E-02	.1315E-02
.417	45.860	.7840E+05	1.141	120.0	123.0	120.0413	122.9774	.1649E-02	.1004E-02
.450	52.128	.8525E+05	1.147	120.0	123.0	119.9638	123.1395	.1739E-02	.9995E-03
.478	58.426	.9340E+05	.991	120.0	123.5	119.9392	123.4168	.8400E-03	.5047E-03
.414	64.661	.9330E+05	1.013	120.0	123.5	119.9172	123.6956	.3374E-02	.1014E-02
.526	70.902	.1033E+06	1.101	120.0	124.0	119.9789	123.8628	.2142E-02	.2180E-02
.540	1.848	.9626E+05	1.210	120.0	124.0	119.9422	124.0490	.3007E-02	.1226E-02
.452	8.205	.9043E+05	1.155	120.0	124.0	119.9972	124.2786	.7559E-03	.5315E-03
.425	14.414	.6324E+05	.967	120.0	124.5	120.0791	124.4920	.2763E-02	.1953E-02
.476	20.787	.4352E+05	1.076	120.0	125.0 *	120.1702	124.6790	.3422E-02	.3748E-02
.425	27.002	.4031E+05	1.166	120.0	125.0	120.2603	124.8989	.1809E-02	.6912E-03
.487	33.280	.3715E+05	1.127	120.5	125.0	120.3677	125.0470	.1471E-02	.1165E-02
.473	39.567	.4232E+05	1.082	120.5	125.0	120.5260	125.1730	.9354E-03	.1047E-02
.5[illegible]	45.043	.7534E+05	1.071	121.0	125.5	120.7141	125.[illegible]	[illegible]	[illegible]
.481	52.184	.7164E+05	[illegible]	121.0	125.5	[illegible]	[illegible]	[illegible]	[illegible]
.43[illegible]	58.427	[illegible]	[illegible]	121.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.450	64.[illegible]	[illegible]	[illegible]	[illegible]	[illegible] *	[illegible]	[illegible]	[illegible]	[illegible]
.43[illegible]	70.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ORIGINAL PAGE IS OF POOR QUALITY

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.50	1.	[illegible]E+05	1.1	1[illegible]	[illegible]	12[illegible] 50	[illegible]5.79	[illegible]1E-0[illegible]	.10[illegible]
.467	8.206	.8248E+05	1.149	122.0	126.0	121.9447	125.8298	.1080E 02	.1742E 02
.506	14.418	.8303E+05	1.144	122.0	126.0	122.1620	125.8353	.1067E 02	.3071E-02
.456	20.771	.6867E+05	1.099	122.5	126.0	122.3366	125.8041	.9002E-03	.2514E 02
.481	27.017	.7173E+05	1.072	122.5	126.0	122.5649	125.7455	.6232E-03	.4700E 02
.443	33.295	.9207E+05	1.100	123.0	126.0	122.7705	125.7718	.4275E 0[illegible]	.3971E 03
.430	39.592	.7207E+05	.991	123.0	125.5	122.9782	125.5976	.2437E 02	.6051E 03
.478	45.857	.6415E+05	.963	123.0	125.5	1[illegible].1867	125.4956	.2725E 02	.6475E 03
.433	52.128	.5725E+05	1.008	123.5	125.5	123.3204	125.3026	.8034E 03	.1041E 02
.503	58.431	.4373E+05	1.100	123.5	125.0	123.4825	125.1927	.1205E-02	.3064E 02
.529	64.750	.4225E+05	1.093	123.5	125.0	123.6257	125.0975	.8537E 03	.1031E 02
.470	70.898	.5797E+05	1.123	124.0	125.0	123.7937	124.8705	.1207E-02	.7204E 03
.471	1.858	.6953E+05	1.035	124.0	124.5	123.9034	124.6578	.8576E 02	.6821E 02
.481	8.213	.6423E+05	.973	124.0	124.5	123.9976	124.4719	.1767E 02	.1504E 02
.518	14.414	.9271E+05	1.153	124.0	124.0	124.0540	124.24[illegible]	.9750E-03	.1741E-02
.478	20.768	.9310E+05	1.173	124.0	124.0	124.1083	124.0527	.8691E-03	.1474E-02
.546	27.012	.1048E+06	1.146	124.0	124.0	124.1332	123.8506	.1894E-02	.2381E-02
.403	33.300	.9121E+05	.978	124.0	123.5	124.1235	123.5886	.1334E-02	.9253E-03
.442	39.582	.9127E+05	1.096	124.0	123.0	124.0981	123.3469	.2190E-02	.2220E 01
.422	45.804	.8546E+05	1.160	124.0	123.0	124.0408	123.1280	.5966E-03	.1493E-02
.445	52.100	.7725E+05	1.163	124.0	123.0	123.9760	122.9731	.1275E-02	.1704E 0[illegible]
.394	58.413	.6682E+05	1.037	124.0	123.0	123.8962	122.7720	.9010E-03	.1767E-0[illegible]
.405	64.670	.4670E+05	.934	124.0	122.5	123.7757	122.5702	.1107E 02	.4740E-03
.422	70.898	.1278E+06	1.163	123.5	122.5	123.6926	122.6044	.1916E-01	.6330E+00
.4[illegible]5	1.842	.7619E+05	1.125	123.5	122.0	123.5065	122.1823	.1073E 02	.7097E-03

ORIGINAL PAGE IS
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delta rt

	1	2	3	4	5	6
0	-.00927	-.02747	-.01561	.00453	.00607	.00788
1	.00282	-.00724	-.00751	-.00837	.00108	.01191
2	.01044	.00696	.00076	-.02117	.01852	.00604
3	.01320	.01576	.00672	.00160	-.01234	[illegible]
4	-.00228	-.01403	[illegible]	.01168	.01454	.00027
5	.00767	.01016	.00042	-.01260	.00053	-.00183
6	.00578	.01478	.00295	-.00718	-.01342	.00377
7	.01857	.00723	-.02672	.01613	.01226	.00210
8	.01471	.00109	.01467	.01770	.00870	.01294
9	.00779	-.00385	.00453	.01862	-.00642	[illegible]

xo= 122.0186 yo= 123.7248 ro= 2.10059381 std.dev.= .01834827

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	1	2	6	19	31	0

ORIGINAL PAGE IS
OF POOR QUALITY

	delta ri					
	1	2	3	4	5	6
0	-.01.49	-.02064	-.01026	.00141	.00370	.00530
1	.00038	-.00952	-.00962	-.01030	-.00066	-.01346
2	.00907	.00572	-.00032	-.02207	.01774	.00542
3	.01275	.0 552	.00633	.00293	-.01756	.00077
4	.00746	-.01501	-.02061	.01344	.01426	-.0[illegible]063
5	.00720	.00958	-.00027		-.00041	-.00495
6	.00448	.01331	.00134	-.00907	-.01539	.00162
7	.01724	.00477	-.02936	-.02892	.00931	-.00059
8	.01152	-.00221	.01129	.01425	.00520	
9	.00424	-.00740	.00100	.01513		.0[illegible]919

x0= 1.2.0202 y0= 123.7243 r0= 2.10245609 std.dev.= .01405497

HISTOGRAM DEVIATION r e

>=	.05	.04	.03	.02	.01	0.00	bad points
	0	0	3	5	17	32	3

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Disk 29-A track data file 1001003

	Coarse	Fine	Track	
NDROI	1.0	1.0	64.0	
Integration delay	.1160E+00	.4574E+00	.1344E 02	
Thresholds	.2290E+06	.9190E+05	.7352E+06	
Constants	.33000	.29400	.37000	.??600
Displacements	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.347	34.270	.2010E+05	2.762	124.0	123.5	124.1017	123.5606	.1514E 02	[illegible]
.324	39.531	.1964E+05	2.902	124.0	123.0	124.0665	123.3023	.7337E-03	.5561E 03
.343	45.607	.1830E+05	2.932	124.0	123.0	124.0123	123.0943	.1832E-02	.6274E 03
.307	52.132	.1700E+05	2.929	124.0	123.0	123.9536	122.9367	.1244E-02	.3567E-03
.299	58.378	.1422E+05	2.860	124.0	123.0	123.8739	122.7216	.1417E-02	.1112E-02
.310	64.643	.1003E+05	2.717	124.0	122.5	123.7745	122.5419	.1040E-02	.1647E-02
.366	70.895	.2917E+05	2.967	123.5	122.0	123.6589	122.4584	.1941E-01	.2708E+00
.318	1.827	.1706E+05	2.913	123.5	122.0	123.4776	122.1540	.8773E-03	.1410E-02
.321	8.180	.1621E+05	2.922	123.5	122.0	123.2909	122.0594	.1099E-02	.4340E-03
.382	14.394	.1832E+05	2.935	123.0	122.0	123.1379	121.9610	.1666E-02	.6698E-03
.363	20.750	.1881E+05	2.930	123.0	122.0	122.9557	121.8336	.1152E-02	.1615E 02
.318	26.984	.2029E+05	2.921	123.0	122.0	122.7589	121.7248	.2267E 02	.1655E 02
.361	33.271	.1008E+05	2.813	122.5	121.5	122.5327	121.6526	.7160E 03	.2745E-03
.310	39.545	.1715E+05	2.796	122.5	121.5	122.29 4	121.6114	.1167E-02	.9830E 03
.318	45.834	.1631E+05	2.821	122.0	121.5	122.0957	121.5967	.1531E-02	.1166E 02
.341	52.105	.1779E+05	2.844	122.0	121.5	121.8772	121.6109	.1609E-02	.4893E-03
.352	58.388	.1631E+05	2.830	121.5	121.5	121.6870	121.6260	.14 11 02	.5863E-03
.303	64.635	.1614E+05	2.845	121.5	121.5	121.4535	121.6575	.7817E-03	.9767E 03
.352	70.902	.1957E+05	2.967	121.0	122.0	121.2447	121.7?23	.1477E 02	.1268E-02
.380	1.816	.1866E+05	2.946	121.0	122.0	121.0196	121.8390	.1676E-02	.6050E-03
.405	0.158	.1857E+05	2.930	121.0	122.0	120.8051	121.9480	.1172E 02	.1045E 02
.372	14.402	.1589E+05	2.882	120.5	122.0	120.6620	122.0577	.8071E-03	.5917E-03
.358	20.723	.1660E+05	2.891	120.5	122.0	120.5074	122.2043	.4149E-03	.1176E 02
.318	27.000	.1046E+05	2.720	120.5	122.5	120.3714	122.4161	.7699E-03	.6529E-03
.302	33.268	.1158E+05	2.724	120.0	122.5	120.215?	122.5525	.8929E-03	.1123E-02
.313	39.551	.1378E+05	2.877	120.0	123.0	120.1149	122.7413	[illegible]	[illegible]
[illegible]	45.8?5	.1674E+05	[illegible]	120.0	123.0	[illegible]	122.9407	[illegible]	[illegible]
.324	52.121	.1840E+05	2.917	[illegible]	123.0	119.9407	123.0987	.1701E 02	[illegible]
.363	58.406	.2317E+05	2.807	120.0	123.5	119.9165	123.2918	.6877E 02	[illegible]
[illegible]	64.635	[illegible]	2.706	[illegible]	123.5	119.8772	[illegible]	.1754E 02	.1007E 02
.406	70.888	[illegible]	[illegible]	[illegible]	124.0	119.9177	123.0106	[illegible]	[illegible]
.417	1.831	.2190E+05	2.904	120.0	124.0	119.9?41	124.0101	.7794E-03	[illegible]
.400	[illegible]	.2077E+05	2.942	[illegible]	124.0	119.97?4	[illegible]	[illegible]	[illegible]
[illegible]	14.401	.1174E+05	2.764	[illegible]	124.5	[illegible]	[illegible]	[illegible]	.5701E 01
.373	20.730	.1322E+05	2.810	120.0	124.5	[illegible]	[illegible]	[illegible]	.5072E 01

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.306	33.203	.9275E+04	2.913	120.5	125.0	120.2493	125.0149	.1312E-02	[illegible]
.330	39.577	.1003E+05	2.882	120.5	125.0	120.5041	125.1360	.1081E-02	.1120E-02
.363	45.865	.1225E+05	2.883	120.5	125.0	[illegible]	125.2929	[illegible]	.1075E-02
.382	52.106	.1588E+05	2.804	121.0	125.5	[illegible]	125.4766	.9216E-03	[illegible]
.369	58.412	.1607E+05	2.785	121.0	125.5	121.0547	125.5671	.1054E-02	.4619E-03
.349	64.654	.1555E+05	2.836	121.0	125.5	121.2403	125.6392	.9495E-03	.5540E-03
.371	70.888	.1748E+05	2.876	121.5	126.0	121.4355	125.7037	.9320E-03	.6604E-03
.318	1.813	.1787E+05	2.891	121.5	126.0	121.6989	125.7500	.1585E-02	.1433E-02
.391	8.165	.2002E+05	2.931	122.0	126.0	121.9220	125.7847	.1276E-02	.1516E-02
.358	14.415	.1975E+05	2.925	122.0	126.0	122.1497	125.7844	.2143E-02	.1542E-02
.425	20.758	.1601E+05	2.895	122.5	126.0	122.3187	125.7607	.1231E-02	.3042E-02
.400	26.995	.1794E+05	2.871	122.5	126.0	122.5464	125.6998	.8150E-03	.1139E-02
.397	33.279	.1783E+05	2.835	123.0	125.5	122.7395	125.6528	.6755E-03	.6056E-03
.350	39.567	.1766E+05	2.781	123.0	125.5	122.9513	125.5692	.1707E-02	.6111E-03
.400	45.842	.1458E+05	2.766	123.0	125.5	123.1602	125.4646	.1961E-02	.7008E-03
.408	52.114	.1170E+05	2.890	123.5	125.0	[illegible]	125.3203	.1309E-02	.4227E-02
.376	58.385	.9972E+04	2.887	123.5	125.0	123.4617	125.1522	.1270E-02	.1401E-02
.363	64.640	.1001E+05	2.875	123.5	125.0	123.6041	124.9990	.7595E-03	.5169E-03
.414	70.891	.1315E+05	2.896	124.0	125.0	123.7739	124.8213	.1042E-02	.4168E-03
.358	1.838	.1364E+05	2.791	124.0	124.5	123.8877	124.6176	.1626E-02	.9780E-03
.389	8.196	.1360E+05	2.771	124.0	124.5	123.9771	124.4444	.8003E-03	.6670E-03
.414	14.405	.2121E+05	2.935	124.0	124.0	124.0323	124.2087	.1774E-02	.1624E-02
.484	20.758	.2249E+05	2.947	124.0	124.0	124.0914	124.0177	.1057E-02	.1111E-02
.429	27.016	.2390E+05	2.922	124.0	124.0	124.1195	123.8018	.1634E-02	.1110E-02

ORIGINAL PAGE IS
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delta ri

	1	2	3	4	5	6
0	.00763	.00218	.00040	-.00503	.01014	.01410
1	-.03349	.03125	-.02067	-.030[illegible]	-.01298	.00547
2	.00449	-.00241	-.00632	-.019[illegible]	-.01425	.00252
3	.00545	-.00759	.01018	.0083[illegible]	.00781	-.02647
4	.01452	.00855	.01011	.0410[illegible]	.00502	.00514
5	.01427	.00131	.00117	-.00855	-.01017	.00714
6	.01776	-.01804	-.02806	.01951	.00396	-.00560
7	.00591	-.01509	-.00076	.00712	-.00154	-.01[illegible]74
8	.00112	.00986	.02417	-.00805	-.02898	-.02716
9	.00712	.00441	.01908	.00019	.01946	.02472

os 131.7725   .04 123.7325   rms 2.0243[illegible]   std.dev.= .01544527

HISTOGRAM DEVIATION >= +

en	.05	.04	.03	.02	.01	0.00	bad points
	0	1	3	7	17	32	0

ORIGINAL PAGE IS
OF POOR QUALITY

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delta ri

	1	2	3	4	5	6
0	.00607	.00456	-.00119	-.00677	.00842	.01226
1		.02952	-.02237	-.03247	-.01460	.00391
2	.00301	-.00300	-.00763	-.02047	-.01538	.00152
3	.00456	-.00834	.00956	.00776	.00340	-.02674
4	.01435	.00849	.01015	.04111	.00526	.00546
5	-.01308	.00175	.00167	-.00762	-.00961	.00771
6	.01833	-.01748	-.02752	.02000	.00441	-.00538
7	-.00558	-.01486	-.00053	.00315	-.00158	-.01371
8	.00085	.00947	.02345	-.00868	-.02973	.02703
9	.00612	.00529	.01787	-.00113	.01807	.02335

u= 121.9995 v0= 123.6878 r0= 2.03909631 std.dev.= .01492262

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	1	10	12	35	1

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TR81-04

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Dwg. 21-A   Track data file TDAT004

	Coarse	Fine	Track	
NDRUN	1.0	1.0	192.0	
Integration delay:	.1160E+00	.4564E+00	.7974E+00	
Thresholds:	.1838E+06	.9190E+05	.7352E+06	
Constants:	.33000	.9400	.37000	.22600
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y		position X	position Y	standard deviation X	standard deviation Y
.464	14.404	.1341E+05	6.157	123.0	122.0		123.1542	121.9980	.3802E-02	.2189E-02
.453	20.762	.1343E+05	6.154	123.0	122.0		122.9742	121.8846	.1952E-02	.4614E-02
.470	27.002	.1353E+05	6.150	123.0	122.0		122.7741	121.7702	.4875E-02	.4052E-02
.452	33.286	.1128E+05	6.121	122.5	122.0		122.5680	121.6649	.3205E-02	.2477E-02
.490	39.588	.1123E+05	6.055	122.5	121.5		122.3159	121.6369	.3483E-02	.3223E-02
.451	45.842	.1121E+05	6.050	122.0	121.5		122.1109	121.6201	.2115E-02	.3654E-02
.462	52.127	.1123E+05	6.025	122.0	121.5		121.8713	121.6328	.1074E-02	.1641E-02
.408	58.403	.1108E+05	6.081	121.5	121.5	*	121.7113	121.6545	.2054E-01	.3364E-02
.432	64.661	.1142E+05	6.162	121.5	122.0		121.4953	121.6625	.1772E-01	.4463E-01
.425	70.873	.1118E+05	6.183	121.0	122.0		121.2563	121.7368	.3556E-02	.5884E-02
.442	1.827	.1112E+05	6.133	121.0	122.0		121.0278	121.8593	.3464E-02	.2513E-02
.478	8.189	.1114E+05	6.108	121.0	122.0		120.8026	121.9579	.2918E-02	.3663E-02
.467	14.334	.1341E+05	6.061	120.5	122.0		120.6795	122.0959	.1798E-02	.4843E-02
.476	20.774	.1346E+05	6.086	120.5	122.0		120.5289	122.2490	.1555E-02	.4210E-02
.422	26.988	.1292E+05	5.878	120.5	122.5		120.4000	122.4651	.2383E-02	.1412E-02
.386	33.267	.1303E+05	5.911	120.0	122.5		120.2306	122.5884	.2123E-02	.1895E-02
.386	39.556	.1353E+05	6.062	120.0	123.0		120.1308	122.7704	.4137E-02	.1572E-02
.394	45.839	.1371E+05	6.083	120.0	123.0		120.0355	122.9523	.3112E-02	.2441E-02
.377	52.140	.1380E+05	6.090	120.0	123.0		119.9486	123.1229	.3447E-02	.2766E-02
.450	58.405	.1402E+05	5.991	120.0	123.5		119.9148	123.4203	.1002E-01	.6352E-02
.355	64.657	.1392E+05	6.007	120.0	123.5		119.9101	123.6269	.3074E-02	.2181E-02
.529	70.898	.1417E+05	6.131	120.0	124.0		119.9559	123.8512	.3099E-02	.5504E-02
.526	1.823	.1409E+05	6.139	120.0	124.0		119.9404	124.0280	.2475E-02	.2254E-02
.473	8.209	.1403E+05	6.033	120.0	124.0		119.9920	124.2477	.2876E-02	.3301E-02
.459	14.423	.1364E+05	5.954	120.0	124.5		120.1021	124.4975	.1739E-02	.1477E-02
.448	20.753	.1360E+05	6.036	120.0	124.5		120.1865	124.6818	.2306E-02	.2011E-02
.464	27.012	.1328E+05	6.075	120.5	125.0	*	120.2754	124.9127	.1740E-01	.1541E-02
.481	33.284	.1321E+05	6.051	120.5	125.0		120.3793	125.0432	.9953E-03	.3100E-02
.437	39.592	.1320E+05	6.034	120.5	125.0		120.5294	125.1675	.1281E-02	.3892E-02
.476	45.046	.1306E+05	5.997	120.5	125.5	*	120.716	125.3843	.2727E-02	.1172E-01
.428	52.1[illegible]	.1100E+05	5.964	[illegible]	125.5		120.[illegible]	125.5090	[illegible]	.5451E-03
.405	58.393	.1024E+05	5.370	121.0	125.5		121.0710	125.5945	[illegible]	.1610E-02
.408	64.774	.10[illegible]E+05	6.0[illegible]	121.0	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
.4[illegible]	70.07[illegible]	.113[illegible]E+05	6.000	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
.4[illegible]	[illegible]	.11[illegible]E+05	6.000	[illegible]	126.0		[illegible]	[illegible]7200	[illegible]	[illegible]

ORIGINAL PAGE IS OF POOR QUALITY

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[illegible]	[illegible]	[illegible]	6.	[illegible]	[illegible]	[illegible]	25.8	[illegible]	[illegible]
.464	14.401	.1142E+05	6.095	122.0	126.0	122.1780	125.8259	.2631E-02	.3027E-02
.433	20.738	.1114E+05	6.084	122.5	126.0	122.2439	125.8007	.2135E-02	.4669E-02
.439	26.999	.1122E+05	6.064	122.5	126.0	122.5654	125.7431	.1976E-02	.3942E-02
.419	33.281	.1326E+05	6.021	123.0	125.5	122.7702	125.6848	.1347E-02	.2294E-02
.453	39.521	.1317E+05	5.955	123.0	125.5	122.9[illegible]	125.6033	.2761E-02	[illegible]
.453	45.044	.1304E+05	5.924	123.0	125.5	123.1727	125.5040	.1867E-02	[illegible]
.442	52.1[illegible]3	.1255E+05	5.974	123.5	125.5	123.31[illegible]	125.3942	.5501E-02	.2745E-02
.439	59.410	.1242E+05	6.028	123.5	125.0	123.4807	125.1900	.1494E-02	.7597E-03
.428	64.640	.1244E+05	6.012	123.5	125.0	123.61[illegible]	125.0461	.1487E-02	[illegible]
.4[illegible]6	70.[illegible]	.1333E+05	6.024	124.0	125.0	123.[illegible]	124.8912	.2600E-02	[illegible]
.44[illegible]	1.01[illegible]	.1367E+05	6.003	124.0	124.5	123.91[illegible]	124.6637	.1780E-01	.1490E-01
.506	8.1[illegible]1	.1349E+05	5.92[illegible]	124.0	124.5	124.00[illegible]	124.4831	.5037E-02	.9755E-03
.4[illegible]0	14.406	.1455E+05	6.124	124.0	124.0	124.0517	124.2492	.2311E-01	.3652E-01
.551	20.766	.1433E+05	6.107	124.0	124.0	124.1030	124.0260	.3309E-02	.1024E-02
.504	27.010	.1440E+05	6.096	124.0	124.0	124.1[illegible]	123.8346	.2659E-02	.2565E-02
.414	33.297	.1394E+05	5.945	124.0	123.5	124.1139	123.5915	.2622E-02	.3505E-02
.347	39.586	.1372E+05	5.941	124.0	123.5	124.0873	123.3934	.4324E-02	.1689E-02
.434	45.885	.1387E+05	6.070	124.0	123.0	124.0255	123.0982	.1488E-02	.2920E-02
.414	52.132	.1381E+05	6.075	124.0	123.0	123.9716	122.9426	.2542E-02	.2305E-02
.376	58.434	.1363E+05	6.021	124.0	123.0	123.8970	122.7535	.2883E-02	.4479E-02
.400	64.671	.1326E+05	5.877	124.0	122.5	123.8078	122.5822	.1012E-01	.6210E-02
.333	70.905	.1240E+05	5.866	123.5	122.5	123.6749	122.4226	.2559E-02	.1253E-02
.439	1.859	.1299E+05	6.094	123.5	122.0	123.5054	122.1904	.1126E-02	.3987E-02
.506	8.232	.1290E+05	6.095	123.5	122.0	123.3200	122.0868	.2841E-02	.3629E-02

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delta ri

	1	2	3	4	5	6
0	-.04376	-.03692	-.01479	.02169	-.00102	-.00294
1	.01351	-.01601	.01966	.01937	.00507	.03876
2	.00276	-.00825	-.05345	.01487	.01274	.02590
3	.05405	.00522	.01069	-.02981	-.00657	-.00242
4	.03120	-.03196	.01268	.00713	-.02350	.01343
5	.01551	-.00019	-.00909	-.02073	.01089	.00049
6	.01003	.00330	-.00685	.00072	.01258	.02478
7	.01548	-.02546	-.03137	.04197	.01117	.0258[illegible]
8	-.00522	.00041	.01118	-.00749	-.01246	-.00587
9	.00465	.00552	.01348	-.00294	.02641	-.01822

x0= 122.0220 y0= 123.7184 r0= 2.10320282 std.dev.= .02074553

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	2	2	5	10	19	22	0

ORIGINAL PAGE IS
OF POOR QUALITY

delta r1

	1	2	3	4	5	6
0	-.04278	-.03600	-.01984	.02?77	-.00001	-.00191
1	.01246			.02045	.00615	.02743
2	.00783	-.00720	-.05241	.01597	.01326	.02687
3	.05499		.01155	[illegible]	-.00578	-.00168
4	.04051	.03131		.00770	.02204	
5	.01595	.00023	-.00950		-.02056	.00000
6	.01031	.00408	-.00659	.0009?	.01293	.02504
7	.01575	-.02518	-.03108	.04??8		.0?620
8		.00085	.01165	-.00790	-.01193	-.00527
9	-.00421	.00620		-.00?18	.02722	-.01745

x0= 122.0222 y0= 123.7188 r0= 2.10253501 std.dev.= .02169273

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	2	2	5	19	12	20	9

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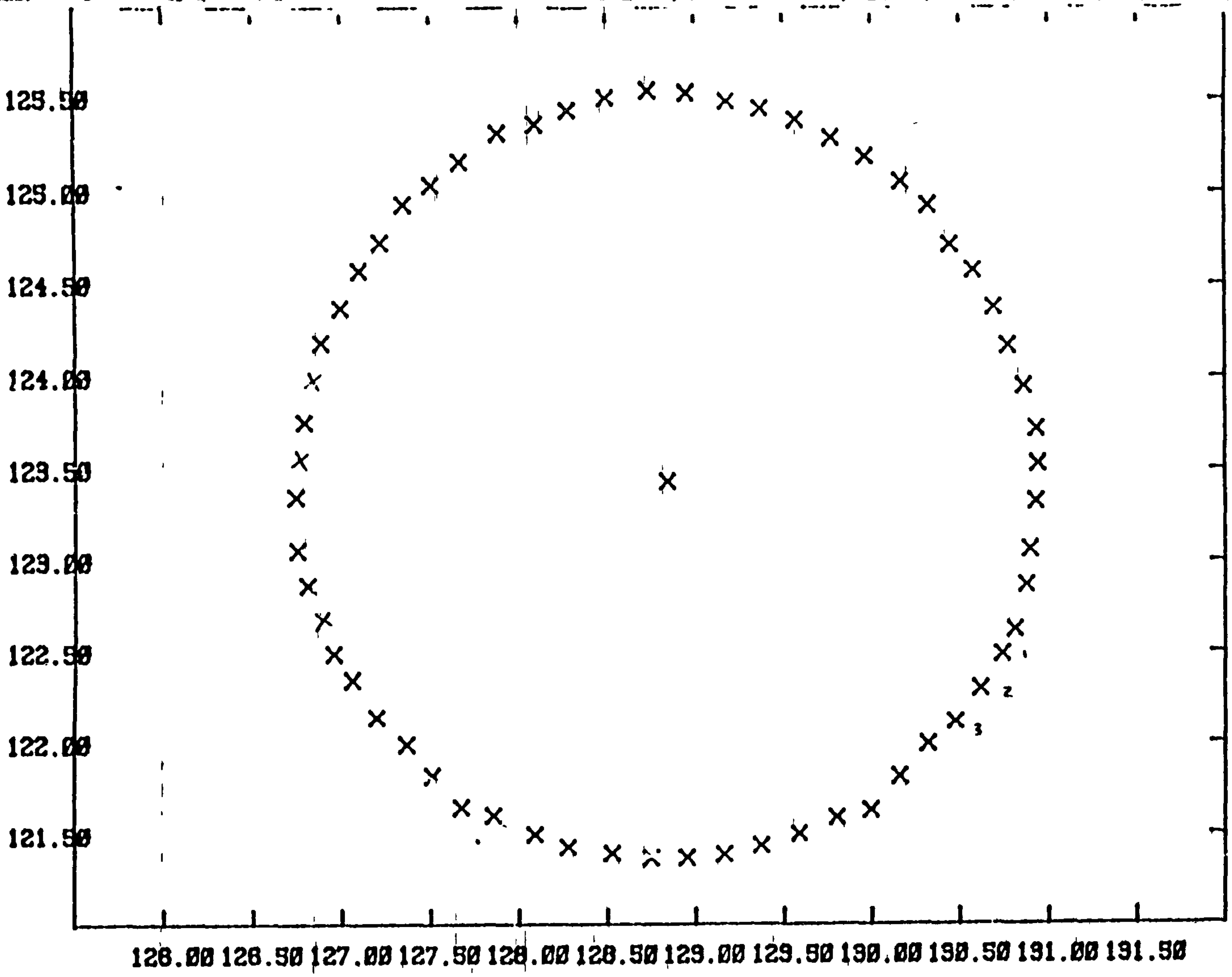

CENTER S.D= 1.846%

ORIGINAL PAGE IS OF POOR QUALITY

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12-B-01 F2.8 +.3M 2 K=.317.255.406.265 100% 0°C

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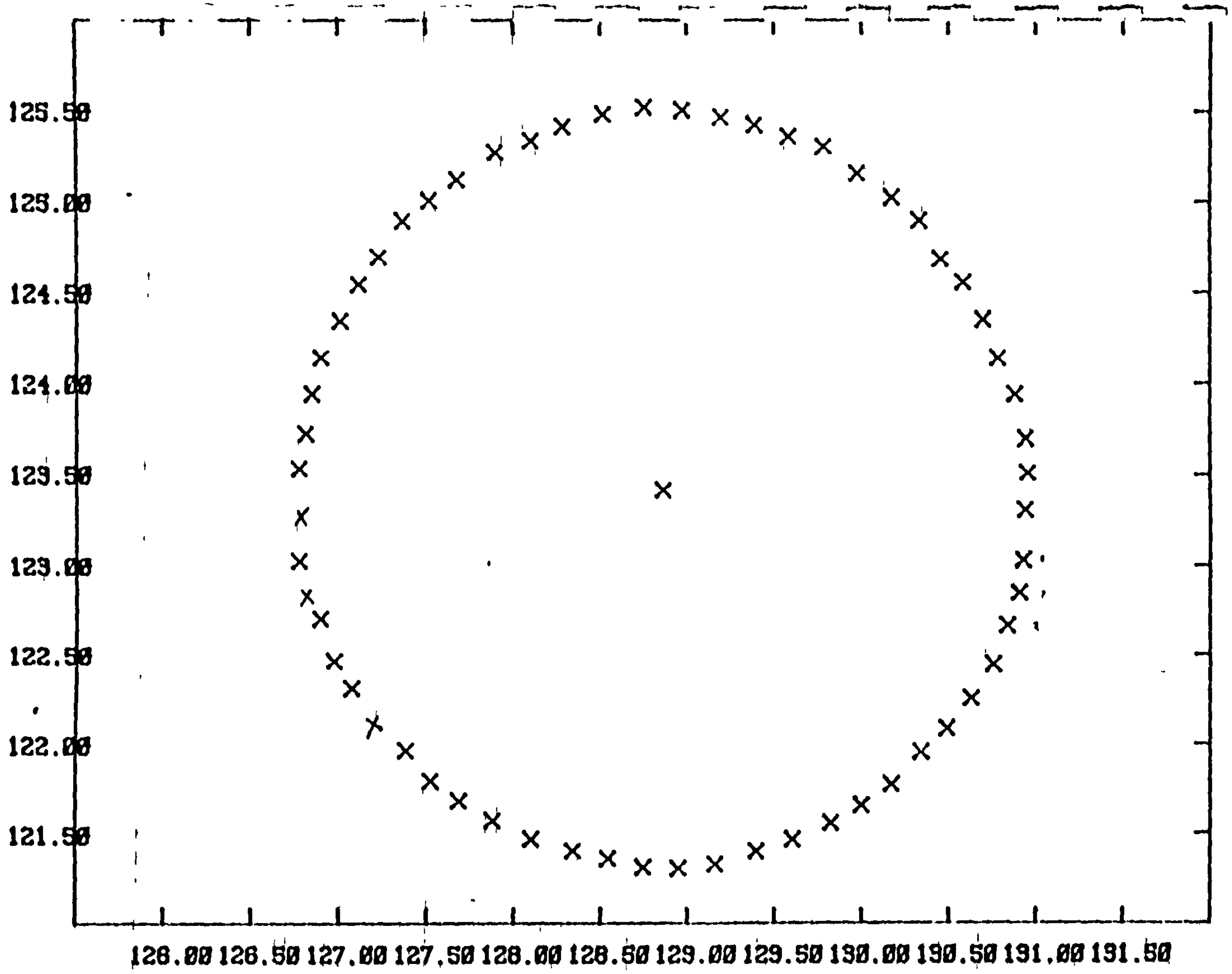

CENTER S.D= 1.614%

12-B-00 F2.8 +.3M 2 K=.317.255.406.265 10% 0°C

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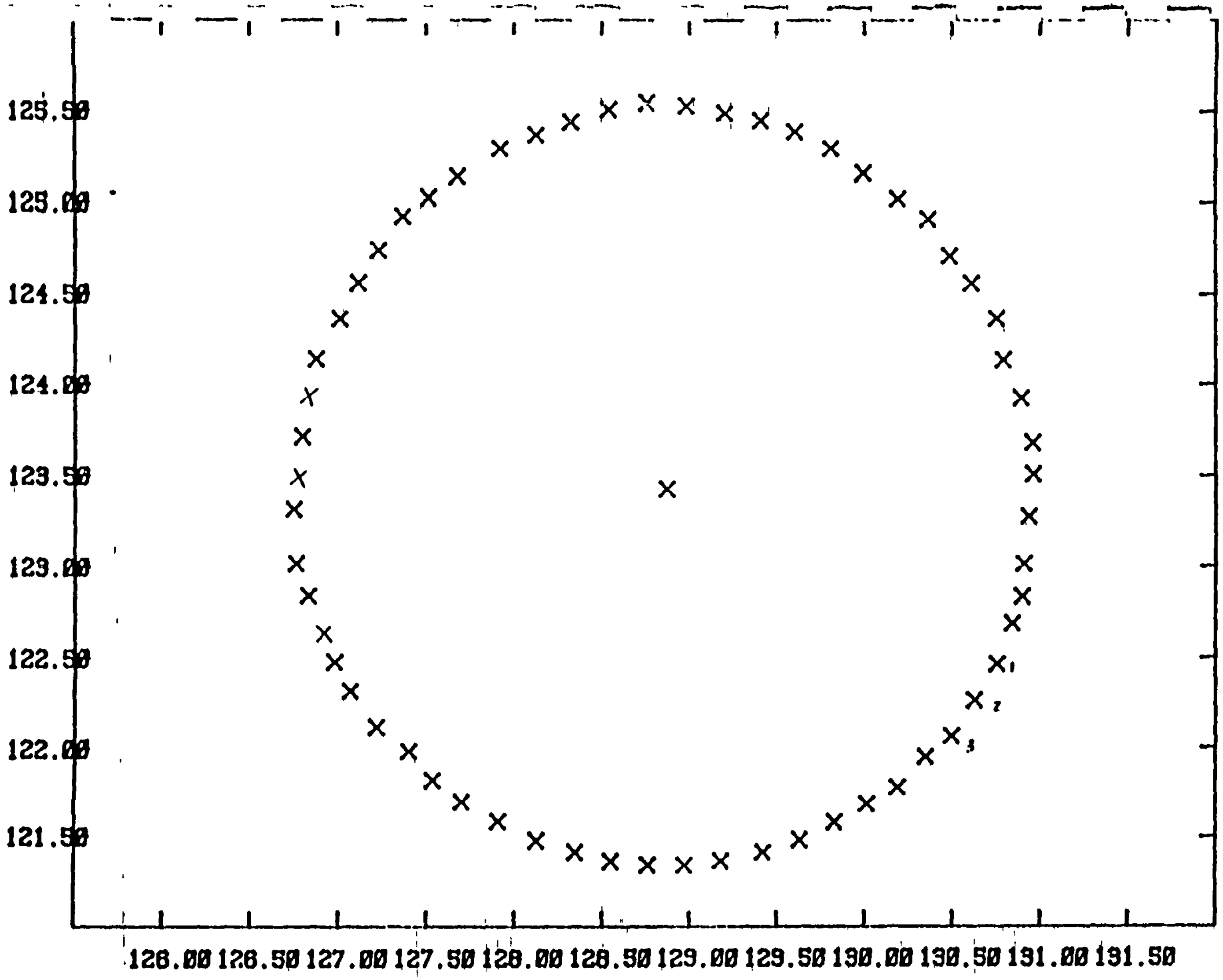

CENTER S.D= 1.733%

12-B-03 F2.8 +.3M 2 K=.317.255.406.265 <1% 0°C

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Disk 12-B   Track data file TDATA01

	Coarse	Fine	Track	
NDROI	1.0	1.0	16.0	
Integration delay	.1170E+00	.4564E+00	.1344E-02	
Thresholds	.1830E+06	.9190E+05	.7352E+06	
Constants	.31700	.25500	.40600	.26500
Displacements	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.366	58.302	.4060E+05	.747	131.0	122.5	130.7300	122.4886	.6747E-03	.9744E-03
.442	64.640	.8094E+05	.911	130.5	122.0	130.6121	122.3054	.7628E-03	.1015E-0[illegible]
.425	70.866	.7858E+05	.957	130.5	122.0	130.4679	122.1179	.7317E-03	.7744E-03
.434	1.009	.7446E+05	.966	130.5	122.0	130.3155	121.9932	.6607E-03	.6441E-03
.422	8.160	.9016E+05	.972	130.0	122.0	130.1533	121.8189	.6344E-03	.1257E-02
.394	14.362	.9708E+05	.964	130.0	122.0	129.9889	121.6379	.9636E-03	.3307E-03
.417	20.724	.9052E+05	.867	130.0	121.5	129.7995	121.5974	.6736E-03	.2649E-03
.422	26.968	.7369E+05	.806	129.5	121.5	129.5830	121.5032	.4721E-03	.8154E-03
.417	33.258	.6106E+05	.831	129.5	121.5	129.3670	121.4350	.9576E-03	.8377E-03
.478	39.409	.5930E+05	.872	129.0	121.5	129.1586	121.3870	.7095E-03	.4987E-03
.400	45.765	.6360E+05	.902	129.0	121.5	128.9467	121.3657	.5666E-03	.4629E-03
.422	52.085	.7200E+05	.921	129.0	121.5	128.7428	121.3677	.6401E-03	.4187E-03
.434	58.373	.5825E+05	.845	128.5	121.5	128.5229	121.3933	.6052E-03	.5430E-03
.389	64.609	.6445E+05	.863	128.0	121.5 *	128.2915	121.4274	.1159E-01	.4692E-02
.478	70.776	.7352E+05	.831	128.0	121.5	128.0050	121.5011	.6037E-03	.7727E-03
.408	1.799	.8378E+05	.847	128.0	121.5	127.8543	121.6106	.8875E-03	.8253E-03
.462	8.178	.8700E+05	.935	127.5	122.0	127.6739	121.6585	.6452E-03	.6456E-03
.439	14.375	.7707E+05	.964	127.5	122.0	127.5072	121.8268	.7754E-03	.9775E-03
.391	20.742	.7612E+05	.962	127.5	122.0	127.3446	121.9968	.4791E-03	.1154E-02
.464	26.963	.8527E+05	.974	127.0	122.0	127.1961	122.1457	[illegible]	[illegible]
.456	33.261	.9311E+05	.931	127.0	122.0	127.0597	122.3544	.1177E-02	.7749E-03
.339	39.538	.4401E+05	.761	127.0	122.5	127.[illegible]542	122.4973	.7433E-03	.6545E-03
.419	45.835	.6405E+05	.884	127.0	123.0	12[illegible].8799	122.6453	.8394E-03	[illegible]
.333	52.076	.8732E+05	.945	127.0	123.0	12[illegible].[illegible]098	122.8690	.8494E-03	.1170E-02
.414	58.321	.9007E+05	.980	127.0	123.0	12[illegible].7503	123.0586	.6762E-03	[illegible]
.432	64.622	.1111E+06	.937	127.0	123.0	127.7415	123.3508	.1250E-02	.5218E-03
.391	70.884	.1164E+06	.910	127.0	123.5	127.7467	123.5591	.1023E-02	.7989E-03
.526	1.802	.1300E+06	.951	127.0	124.0	12[illegible].7875	123.7545	.1380E-02	.1057E-02
.481	8.174	.1158E+06	1.028	127.0	124.0	12[illegible].0237	123.9651	.1464E-02	.9240E-03
.478	14.348	.1042E+06	1.018	127.0	124.0	12[illegible]	124.1017	.6097E-03	.6716E-03
.434	20.727	.7670E+05	.861	127.0	124.5	[illegible]	124.3718	[illegible]	[illegible]
.432	26.971	[illegible]	[illegible]	127.0	12[illegible]	[illegible]1001	124.5[illegible]	[illegible]	[illegible]
.470	[illegible]	.4470E+06	[illegible]	127.0	12[illegible]	[illegible]	124.7[illegible]	[illegible]	[illegible]
.506	[illegible]	.4157E+06	[illegible]	127.5	12[illegible]	[illegible]	12[illegible].[illegible]14	[illegible]	[illegible]
.472	[illegible]	.4041E+06	[illegible]	127.5	12[illegible]	[illegible]	125.0[illegible]	[illegible]	[illegible]

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.4[illegible]	[illegible]	[illegible]	[illegible]	[illegible].5	[illegible].0	[illegible]92	[illegible]	.[illegible]27E-0[illegible]	.[illegible]-02
.501	50.337	.6623E+05	.970	128.0	125.0	127.0[illegible]40	125.3106	.9061E-03	.8220E-03
.467	64.626	.7003E+05	.881	128.0	125.5	128.0[illegible]20	125.3600	.7515E-03	.1330E-02
.512	70.776	.7550E+05	.871	128.0	125.5	128.2812	125.4320	.9665E-03	.1303E-02
.492	1.802	.7740E+05	.817	128.5	125.5	128.4996	125.5045	.1057E-02	.7957E-03
.490	8.181	.2413E+05	.870	129.0	125.5	128.7[illegible]53	125.5446	.7[illegible]E-03	.[illegible]E-03
.495	14.376	.8545E+05	.827	129.0	125.5	128.[illegible]	125.5[illegible]	.1594E-02	.[illegible]E-03
.504	20.751	.8070E+05	.852	129.0	125.5	129.1[illegible]	125.4867	.1309E-02	.7045E-03
.498	27.[illegible]3	.724[illegible]E+05	.870	129.5	125.5	129.[illegible]	125.4449	.1020E-02	.[illegible]E-03
.473	33.246	.7038E+05	.878	129.5	125.5	129.5[illegible]	125.3055	.9022E-03	.[illegible]E-03
.476	39.534	.7157E+05	.953	130.0	125.5	129.7714	125.2904	.8075E-03	.[illegible]E-03
.431	45.777	.5442E+05	.977	130.0	125.0	129.9[illegible]	125.1099	.1745E-02	.1131E-02
.453	52.083	.4253E+05	.760	130.0	125.0	130.1671	125.0534	.12[illegible]E-02	.12[illegible]E-0[illegible]
.481	58.374	.3946E+05	.947	130.5	125.0	130.3209	124.9267	.6[illegible]E-03	.6[illegible]E-03
.464	64.619	.4476E+05	.922	130.5	125.0	130.4434	124.7142	.4597E-03	.7[illegible]E-03
.464	70.852	.6863E+05	.814	130.5	124.5	130.[illegible]	124.5743	.8[illegible]E-03	.7574E-03
.501	1.816	.6780E+05	.842	130.5	124.5	130.[illegible]03	124.3730	.1[illegible]E-02	.7[illegible]E-03
.577	8.181	.1106E+06	1.005	131.0	124.0	130.7656	124.1684	.1408E-02	.5640E-03
.498	14.384	.1192E+06	1.006	131.0	124.0	130.8716	123.9493	.2784E-03	.1200E-02
.518	20.755	.1287E+06	.960	131.0	124.0	130.9262	123.7155	.9703E-03	.1480E-02
.371	26.965	.1093E+06	.829	131.0	123.5	130.9373	123.5267	.7462E-03	.4047E-03
.450	33.241	.1036E+06	.964	131.0	123.0	130.9261	123.3243	.1101E-02	.3754E-03
.472	39.951	.7420E+05	1.006	131.0	123.0	130.[illegible]29	123.0596	.4253E-03	.1168E-02
.442	45.804	.8611E+05	.953	131.0	123.0	130.8706	122.8717	.9777E-03	.1387E-02
.431	52.076	.6573E+05	.867	131.0	123.0	130.8055	122.6216	.8142E-03	.9714E-03

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	1	2	3	4	5	6
0	.02670	.01446	.00690	-.02428	-.00487	.04553
1	.01449	-.01703	-.01952	.01520	-.01600	-.01658
2	-.02209	-.00727	-.01251	-.01504	.03018	-.00029
3	-.02867	.00005	-.00671	.01898	.02281	.01910
4	.03376	.01063	.00740	.01235	-.00479	.00670
5	.02224	-.01084	-.01770	.02372	-.00075	-.00198
6	.02326	-.02375	-.01512	.00856	.02367	.00081
7	-.00825	-.00997	-.00573	-.01184	-.00273	.00528
8	.01442	-.03626	-.01142	-.01240	-.02290	-.00109
9	.01993	.01236	.00211	-.00006	.02030	.04018

delta r1

x0= 128.8337 y0= 123.4352 r0= 2.00828807 std.dev.= .01832214

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	2	3	12	22	21	0

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delta r1

	1	2	3	4	5	6
0	.02652	.01425	.00667	-.01453	-.00518	.04523
1	.01400	-.01817	-.01987	-.01556	-.01637	-.01896
2	-.02247		-.01289	-.01541	.03581	-.00065
3	.02902	-.00028	-.00703	.01668	.02352	.01804
4	.03352	.01043	.00722	-.01251	-.00492	.00650
5	.02231	-.01089	-.01773	.01372	-.00173	-.00374
6	.02332	-.02367	-.01503	.00867	.02378	.00893
7	-.00812	-.00984	-.00561	-.01172	-.00261	.00539
8	.01451	-.03618	-.01135	-.01235	-.02287	-.00109
9	.01990	.01231	.00204	-.00017	.02017	.04002

x0= 120.8386 y0= 123.4350 r0= 2.08841515 std.dev.= .01845740

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	2	3	12	22	20	1

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Disk 12-B   Track data file 1001000   Center

	Coarse	Fine	Track	
NIROI	1.0	1.0	64.0	
Integration delay:	.1160E+00	.4564E+00	.1344E-02	
Thresholds:	.1838E+06	.9190E+05	.7352E+06	
Constants:	.31700	.25500	.40600	.26500
Displacements:	0.00000	0.00000	0.00000	0.00000

		dark	star	reference		position		standard deviation	
temp	angle	current	mag.	X	Y	X	Y	X	Y
.442	39.540	.1934E+05	2.756	131.0	123.0	130.9253	123.0338	.2664E-02	.5521E-03
.414	45.814	.1761E+05	2.704	131.0	123.0	130.9020	122.8473	.1363E-02	.1668E-02
.383	52.093	.1262E+05	2.568	131.0	122.5	130.8356	122.6640	.9333E-02	.5716E-02
.391	58.378	.8190E+04	2.573	131.0	122.5	130.7550	122.4513	.1203E-02	.1051E-02
.425	64.635	.1771E+05	2.692	130.5	122.0	130.6266	122.2569	.9373E-03	.8342E-03
.417	70.838	.1717E+05	2.724	130.5	122.0	130.4874	122.0894	.1921E-02	.1255E-02
.470	1.798	.1679E+05	2.725	130.5	122.0	130.3360	121.9613	.1092E-02	.1071E-02
.467	8.171	.2076E+05	2.739	130.0	122.0	130.1682	121.7788	.1291E-02	.1359E-02
.459	14.384	.1822E+05	2.657	130.0	121.5	129.9971	121.6615	.1161E-02	.1530E-02
.456	20.728	.1893E+05	2.633	130.0	121.5	129.8194	121.5642	.2053E-02	.9243E-03
.473	26.947	.1466E+05	2.585	129.5	121.5	129.6000	121.4731	.7760E-03	.1344E-02
.456	33.252	.1249E+05	2.616	129.5	121.5	129.3917	121.4079	.1549E-02	.2127E-02
.520	39.555	.1219E+05	2.730	129.0	121.0	129.1535	121.3324	.1083E-02	.1027E-02
.436	45.820	.1313E+05	2.757	129.0	121.0	128.9448	121.3113	.9227E-03	.1865E-02
.425	52.115	.1508E+05	2.786	129.0	121.0	128.7422	121.3179	.7243E-03	.1248E-02
.504	58.367	.1205E+05	2.628	128.5	121.5	128.5493	121.3676	.1493E-02	.1257E-02
.432	64.606	.1263E+05	2.605	128.5	121.5	128.3497	121.4119	.1293E-02	.1777E-02
.445	70.866	.1524E+05	2.598	128.0	121.5	128.0990	121.4744	.5728E-03	.8650E-03
.425	1.823	.1776E+05	2.606	128.0	121.5	127.8774	121.5797	.9552E-03	.1014E-02
.462	8.172	.1567E+05	2.644	127.5	121.5	127.6968	121.6874	.6225E-03	.6237E-03
.471	14.173	.1785E+05	2.733	127.5	122.0	127.5241	121.7993	.1008E-02	.1193E-02
.450	20.734	.1701E+05	2.727	127.5	122.0	127.3817	121.9697	.1020E-02	.9520E-03
.401	26.965	.2077E+05	2.739	127.0	122.0	127.2141	122.1121	.1073E-02	.1215E-02
.419	33.261	.2113E+05	2.698	127.0	122.0	127.0736	122.3145	.1853E-02	.7849E-03
.405	39.551	.9387E+04	2.524	127.0	122.5	126.9753	122.4601	.1002E-02	.1214E-02
.400	45.821	.1332E+05	2.601	127.0	122.5	126.8750	122.6705	.8619E-02	.2405E-01
.400	52.085	.1785E+05	2.633	127.0	123.0	126.8551	122.8464	.1847E-02	.1006E-02
.383	58.373	.2044E+05	2.734	127.0	123.0	126.7710	123.0288	.1075E-02	.1762E-02
.391	64.634	.2309E+05	2.702	127.0	123.0	126.7641	123.3111	.9109E-03	.4591E-02
.383	70.884	.2424E+05	2.575	127.0	123.5	126.7717	123.5137	.1800E-02	.1131E-02
.404	1.031	.2831E+05	2.721	127.0	124.0	126.6114	123.7474	.1831E-02	.1129E-02
.543	8.105	.2562E+05	2.787	127.0	124.0	126.6459	123.9456	.1297E-02	.1108E-02
.504	14.369	[illegible]	2.702	127.0	124.0	[illegible]	124.1425	.1108E-02	.1050E-02
.451	20.770	.1414E+05	[illegible]	127.0	124.5	[illegible]	[illegible]	[illegible]	[illegible]
.492	26.267	[illegible]	2.504	127.0	124.5	[illegible]	124.5400	[illegible]	[illegible]

ORIGINAL PAGE IS OF POOR QUALITY

TR81-04

68

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]279	124.7007	.9169E-03	[illegible]
.452	39.570	.9193E+04	2.709	127.5	125.0	127.3649	124.9027	.3090E-03	.1540E-02
.478	45.827	.9033E+04	2.708	127.5	125.0	127.5165	125.0125	.2149E-02	.1468E-02
.450	52.074	.1018E+05	2.704	127.5	125.0	127.6762	125.1227	.2472E-03	.1728E-02
.432	58.325	.1407E+05	2.717	128.0	125.0	127.8964	125.2742	.1717E-02	.1796E-02
.473	64.620	.1453E+05	2.748	128.0	125.5	128.1001	125.3414	.1713E-02	.1691E-02
.422	70.073	.1486E+05	2.621	128.5	125.5	128.2987	125.4208	.5342E-02	.1490E-02
.478	1.016	.1599E+05	2.586	128.5	125.5	128.5148	125.4871	.8365E-03	.1751E-03
.456	8.189	.1905E+05	2.636	129.0	125.5	128.7520	125.5244	.1104E-02	.1250E-02
.428	14.307	.1808E+05	2.627	129.0	125.5	128.9689	125.5008	.1468E-02	.6792E-03
.449	20.756	.1679E+05	2.615	129.0	125.5	129.1900	125.4712	.1117E-02	.1765E-02
.420	26.971	.1507E+05	2.630	129.5	125.5	129.3864	125.4293	.5973E-03	.1129E-02
.431	33.245	.1430E+05	2.632	129.5	125.5	129.5006	125.3607	.7006E-03	.1906E-02
.456	39.558	.1549E+05	2.731	130.0	125.0	129.7807	125.3113	.2121E-02	.4119E-02
.412	45.811	.1177E+05	2.726	130.0	125.0	129.9775	125.1573	.1449E-02	.2957E-02
.453	52.003	.9571E+04	2.712	130.0	125.0	130.1739	125.0262	.2378E-02	.2004E-02
.473	58.364	.8809E+04	2.705	130.5	125.0	130.3319	124.9032	.7045E-03	.1460E-02
.401	64.618	.9783E+04	2.681	130.5	125.0	130.4557	124.6947	.1034E-02	.1424E-02
.407	70.087	.1417E+05	2.573	130.5	124.5	130.5835	124.5560	.1744E-02	.2165E-02
.509	1.830	.1415E+05	2.620	130.5	124.5	130.6977	124.3580	.2089E-02	.1668E-02
.501	8.198	.2440E+05	2.766	131.0	124.0	130.7842	124.1475	.1409E-02	.1115E-02
.509	14.361	.2623E+05	2.766	131.0	124.0	130.8810	123.9381	.1959E-02	.1119E-02
.520	20.747	.2046E+05	2.725	131.0	124.0	130.9425	123.7029	.2135E-02	.1451E-02
.428	26.368	.2272E+05	2.590	131.0	123.5	130.9521	123.3097	.1345E-02	.1620E-02
.431	33.252	.2161E+05	2.720	131.0	123.0	130.9394	123.2979	.1201E-02	.1458E-02

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TR81-06

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delta ri

	1	2	3	4	5	6
0	.01081	.02976	.02343	.03546	.02143	.00767
1	-.01991	.00293	-.00237	-.00786	-.01478	-.01670
2	.00988	.01203	.00690	-.02113	-.02396	-.01076
3	-.01165	-.00504	.00328	-.01550	.00630	.00571
4	.01697	.00868	.01162	.03234	.00772	.00136
5	-.01600	-.00678	.00542	-.01547	-.00718	.01034
6	.02154	.00003	-.00917	.00920	-.01543	-.00337
7	.01467	.02628	.01088	-.00914	-.00372	-.00337
8	.02208	.01600	-.00704	.00789	-.04194	-.01529
9	-.02144	-.02848	-.00010	.01422	.00582	.00714

u= 128.8530   v0= 123.4112   r0= 2.00962011   std.dev.= .0160490

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	2	11	18	28	0

ORIGINAL PAGE IS
OF POOR QUALITY

TR81-04

delta ri

	1	2	3	4	5	6
0	.01071	.02967	.02337	.03541	.02141	.00768
1	-.01987	.00299	-.00228	-.00773	-.01462	-.01751
2	.01010	.01228	.00718	-.02083	-.02363	-.01060
3	-.01127	-.00464	.00369	-.02508	.00681	.00615
4	.01742		.01206	.03278	.00815	.00177
5	-.01640	-.00640	.00577	-.01513	-.00686	-.01004
6	.02101	.00027	-.00895	[illegible]	.01528	[illegible]
7	.01475	.02633	.01091	-.00314	-.00374	-.00342
8	.02202	-.01609	-.00714	.00777	-.04207	-.01941
9	-.02158	-.02042	-.00024	.01403	.00569	[illegible]

x0= 128.0593 y0= 123.4113 r0= 2.08946872 std.dev.= .01613520

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	2	11	19	26	1

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TR81-04

Disk 12-B   Track data file TDATA03

	Coarse	Fine	Track
NDROI	1.0	1.0	192.0
Integration delay:	.1140E+00	.4564E+00	.7974E+00
Thresholds:	.1030E+06	.9190E+05	.7352E+04

Constants:	.31700	.25500	.40600	.26500
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.450	50.767	.1176E+05	5.751	131.0	122.5	130.7507	122.4664	.2677E-02	.1510E-02
.490	64.606	.1074E+05	5.957	130.5	122.0	130.6227	122.2745	.9544E-02	.5[illegible]E-01
.464	70.030	.1034E+05	5.952	130.5	122.0	130.4936	122.0675	.2067E-02	.4651E-02
.461	1.803	.1035E+05	5.963	130.5	122.0	130.3452	121.9490	.1984E-02	.1459E-02
.504	8.195	.1068E+05	5.970	130.0	122.0	130.1842	121.7745	.1646E-02	.4406E-02
.467	14.396	.1064E+05	5.924	130.0	121.5	130.0084	121.6802	.1950E-02	.1069E-02
.476	20.740	.1066E+05	5.898	130.0	121.5	129.8288	121.5789	.1399E-02	.1253E-02
.476	26.963	.1042E+05	5.868	129.5	121.5	129.6650	121.4866	.1717E-02	.2597E-02
.470	33.274	.1030E+05	5.892	129.5	121.5	129.4164	121.4161	.1286E-02	.2082E-02
.484	39.528	.1019E+05	5.920	129.0	121.5	129.1749	121.3678	.3077E-02	.1784E-02
.490	45.836	.1022E+05	5.942	129.0	121.5	128.9657	121.3454	.1501E-02	.1370E-02
.520	52.078	.1034E+05	5.967	129.0	121.5	128.7582	121.3477	.7646E-03	.1703E-02
.478	58.370	.1263E+05	5.923	128.5	121.5	128.5464	121.3686	.2053E-02	.2040E-02
.515	64.622	.1270E+05	5.896	128.5	121.5	128.3460	121.4157	.5495E-03	.2111E-02
.504	70.859	.1274E+05	5.863	128.0	121.5	128.1234	121.4793	.1389E-02	.1604E-02
.473	1.802	.1290E+05	5.880	128.0	121.5	127.9082	121.5816	.1415E-02	.2152E-02
.501	8.176	.1205E+05	5.938	127.5	121.5	127.6972	121.6926	.2421E-02	.1645E-02
.434	14.390	.1229E+05	6.012	127.5	122.0	127.5315	121.8105	.2102E-02	.4244E-02
.470	20.750	.1221E+05	5.977	127.5	122.0	127.3959	121.9842	.7947E-03	.2074E-02
.518	26.966	.1250E+05	5.990	127.0	122.0	127.2139	122.1172	.1622E-02	.3761E-02
.473	33.259	.1251E+05	5.947	127.0	122.0	127.0[illegible]	122.3172	.1567E-02	.2[illegible]E-02
.411	39.520	.1100E+05	5.709	127.0	122.5	126.9769	122.4794	.[illegible]E-02	.2262E-02
.456	45.805	.1197E+05	5.853	127.0	122.5	126.9066	122.6844	.1965E-02	.1251E-02
.445	52.107	.1262E+05	5.960	127.0	123.0	126.8265	122.8413	.217[illegible]E-02	.[illegible]E-02
.440	58.364	.1276E+05	6.001	127.0	123.0	126.7570	123.0210	.2490E-02	.2450E-02
.456	64.604	.1294E+05	5.978	127.0	123.0	126.7439	123.3144	.3021E-02	.3819E-02
.464	70.027	.1300E+05	5.800	127.0	123.5	126.7579	123.5461	.2427E-02	.1305E-02
.5[illegible]	1.774	.1339E+05	6.029	127.0	124.0	126.7505	123.7103	.6274E-02	.7689E-02
.607	8.164	.1320E+05	6.080	127.0	124.0	126.[illegible]	123.9331	.2697E-02	.2164E-02
.568	14.381	.1307E+05	6.068	127.0	124.0	126.8739	124.1411	.[illegible]E-02	.3431E-02
.501	20.713	.1220E+05	5.916	127.0	124.5	127.00[illegible]	124.[illegible]	.14[illegible]E-02	.[illegible]E-02
.517	[illegible]	.12[illegible]E+05	5.[illegible]	127.0	124.5	127.[illegible]	124.[illegible]	.[illegible]E-02	.[illegible]E-02
.5[illegible]	[illegible]	.1211E+05	5.[illegible]	127.0	[illegible]	127.[illegible]	124.[illegible]	.[illegible]E-02	.[illegible]E-02
.5[illegible]	[illegible]	.1104E+05	5.[illegible]	127.5	[illegible]	12[illegible]	124.[illegible]	.[illegible]E-02	.[illegible]E-02
.5[illegible]	45.[illegible]	.1104E+05	5.[illegible]	127.5	[illegible]	127.[illegible]	12[illegible]	.[illegible]E-02	.[illegible]

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.51	52.[illegible]	[illegible]E+05	5.5[illegible]	[illegible]	[illegible].0	[illegible]51	[illegible]5.1[illegible]	.1[illegible]9E-02	.16[illegible]-02
.404	58.364	.1283E+05	5.974	128.0	125.0	127.9186	125.2924	.2493E-02	.1715E-02
.484	64.600	.1287E+05	5.924	128.0	125.5	128.1291	125.3694	.3360E-02	.1670E 02
.473	70.870	.1293E+05	5.914	128.5	125.5	128.3233	125.4424	.2371E-02	.2441E 02
.520	1.001	.1297E+05	5.891	128.5	125.5	128.5402	125.5006	.877[illegible] 03	.1730E-02
.476	8.17[illegible]	.1070E+05	5.9[illegible]	129.0	125.5	12[illegible].7574	12[illegible].5490	.2340E 02	.21[illegible] 02
.473	14.352	.1059E+05	5.917	129.0	125.5	1[illegible].9812	125.5255	.1334E 02	.2014E 02
.407	20.746	.1051E+05	5.908	129.0	125.5	12[illegible].2002	125.4880	.2295E 02	.10[illegible] 02
.462	26.956	.1038E+05	5.936	129.5	125.5	12[illegible].4097	125.4487	.0517E 03	.91[illegible] 01
.475	33.261	.1033E+05	5.945	129.5	125.5	12[illegible].2047	125.3804	.2128E 02	.1221E 02
.456	39.53[illegible]	.1037E+05	6.010	130.0	125.5	1[illegible].0084	125.2092	.[illegible]54E-02	.1527E 02
.464	45.006	.1017E+05	5.981	130.0	125.0	129.9941	125.1549	.10[illegible]-02	.3693E 02
.490	52.073	.1007E+05	5.977	130.0	125.0	130.1880	125.0235	.2072E-02	.2517E 02
.506	58.375	.9974E+04	5.991	130.5	125.0	130.3629	124.9097	.1295E-02	.1381E-02
.475	64.613	.1001E+05	5.979	130.5	125.0	130.4806	124.7071	.1457E-02	.2270E-02
.467	70.834	.1004E+05	5.877	130.5	124.5	130.6074	124.5611	.1550E-02	.2135E 02
.404	1.784	.1176E+05	5.928	131.0	124.5 *	130.7405	124.3685	.1370E-01	.1457E-02
.537	8.161	.1317E+05	6.002	131.0	124.0	130.7892	124.1377	.1237E 02	.1162E 02
.577	14.365	.1332E+05	6.008	131.0	124.0	130.6889	123.9229	.1546E-02	.4309E 02
.529	20.727	.1342E+05	6.061	131.0	124.0	130.9579	123.6789	.3074E-02	.419[illegible] 02
.[illegible]6	27.976	.1277E+05	5.905	131.0	123.5	130.9628	123.5093	.1727E-02	.2714E 02
.442	33.245	.1271E+05	5.998	131.0	123.0	130.9319	123.2752	.187[illegible]E-02	.[illegible] 02
.403	39.512	.1259E+05	6.029	131.0	123.0	130.9064	123.0162	.2557E-02	.2590E 02
.422	45.809	.1250E+05	5.907	131.0	123.0	130.8925	122.8353	.2483E-02	.3724E-02
.492	52.078	.1212E+05	5.868	131.0	122.5 *	130.8384	122.6486	.1552E-01	.3237E 01

ORIGINAL PAGE IS
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delta ri

	1	2	3	4	5	6
0	.02668	.01307	.03121	.00115	.02335	-.00382
1	-.00773	-.00871	-.00807	-.01146	-.01043	-.01296
2	-.01265	-.01095	-.01267	-.01867	-.00701	-.00899
3	-.03976	.00836	.01146	.01272	-.00556	.02077
4	.04731	.02370	.01107	-.00547	.00409	.01527
5	-.02123	-.01225	-.00064	.02703	-.00422	-.01559
6	-.00535	-.01938	-.00903	.01139	.02677	.00759
7	-.00549	.00083	.00375	-.00435	-.02720	-.01735
8	.01726	-.02645	-.01073	.00919	-.03776	-.00520
9	.01916	.01058	-.01637	-.00660	.02298	.04207

x0= 120.0592 y0= 123.4269 r0= 2.09461284 std.dev.= .01759082

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	4	10	22	23	0

ORIGINAL PAGE IS OF POOR QUALITY

TR81-04

74

delta ri

	1	2	3	4	5	6
0	.02964		.03407	.00393	.02601	-.00127
1	.00532	-.00646	-.00599	-.00258	-.00874	-.01146
2	.01135	-.01705	-.01181	-.01801	-.00658	-.00174
3	-.03959	.00825	.01118	.01231	-.00610	.02013
4	.04559	.02287	.01019	-.00639	.00316	.01434
5	-.02213	-.01309	-.00141	.02215	-.00401	-.01607
6	.00564	-.01951	-.00899	.01162	.02721	.00821
7	-.00466	.00186	.00498	.00291	-.02555	-.01550
8	.01928	-.02424	-.00837		-.03511	-.00242
9	.02203	.01351	-.01338	-.00358	.02602	

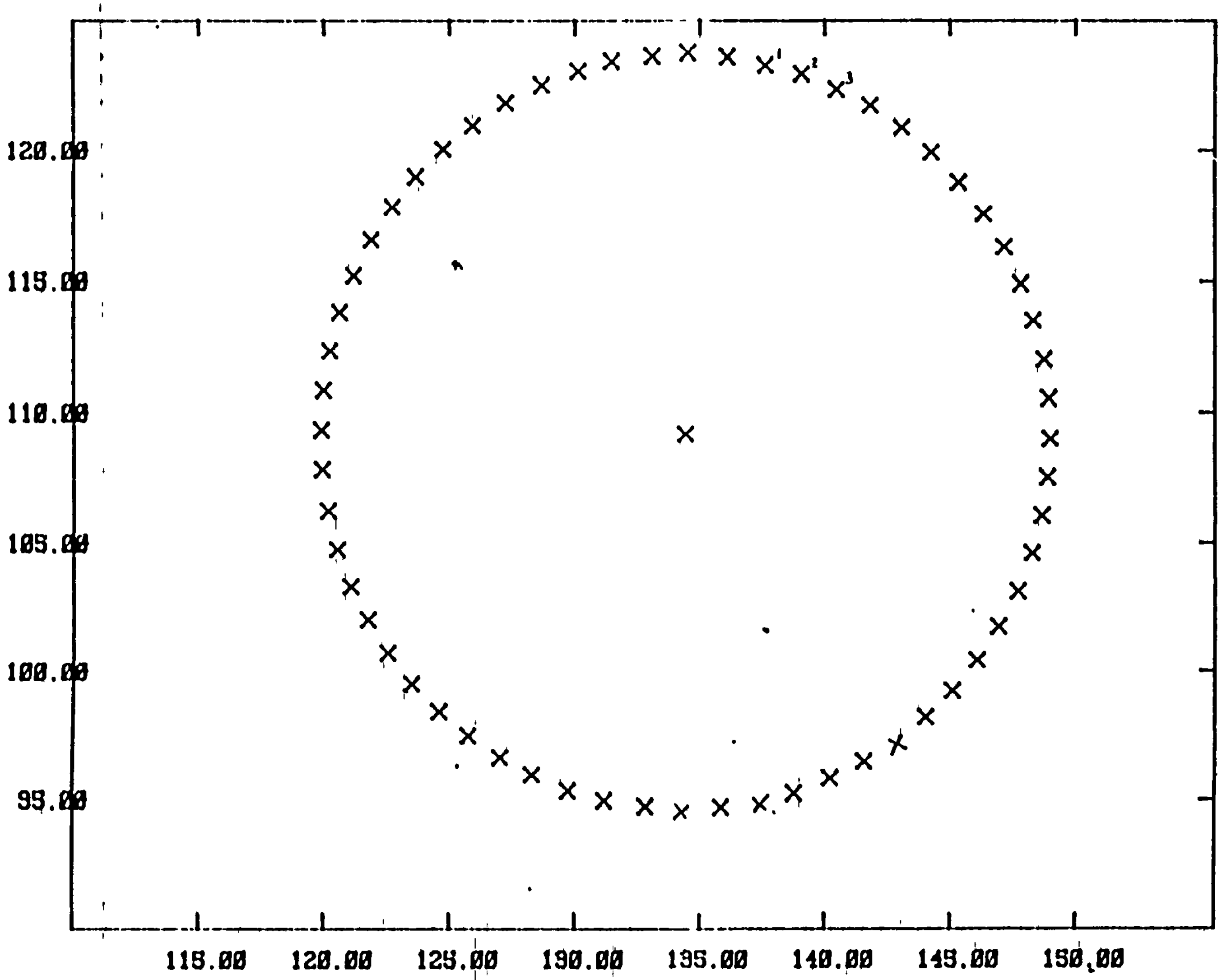
x0= 120.0573   y0= 123.4274   r0= 2.09956380   std.dev.= .01732696

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	1	3	11	17	25	3

ORIGINAL PAGE IS OF POOR QUALITY

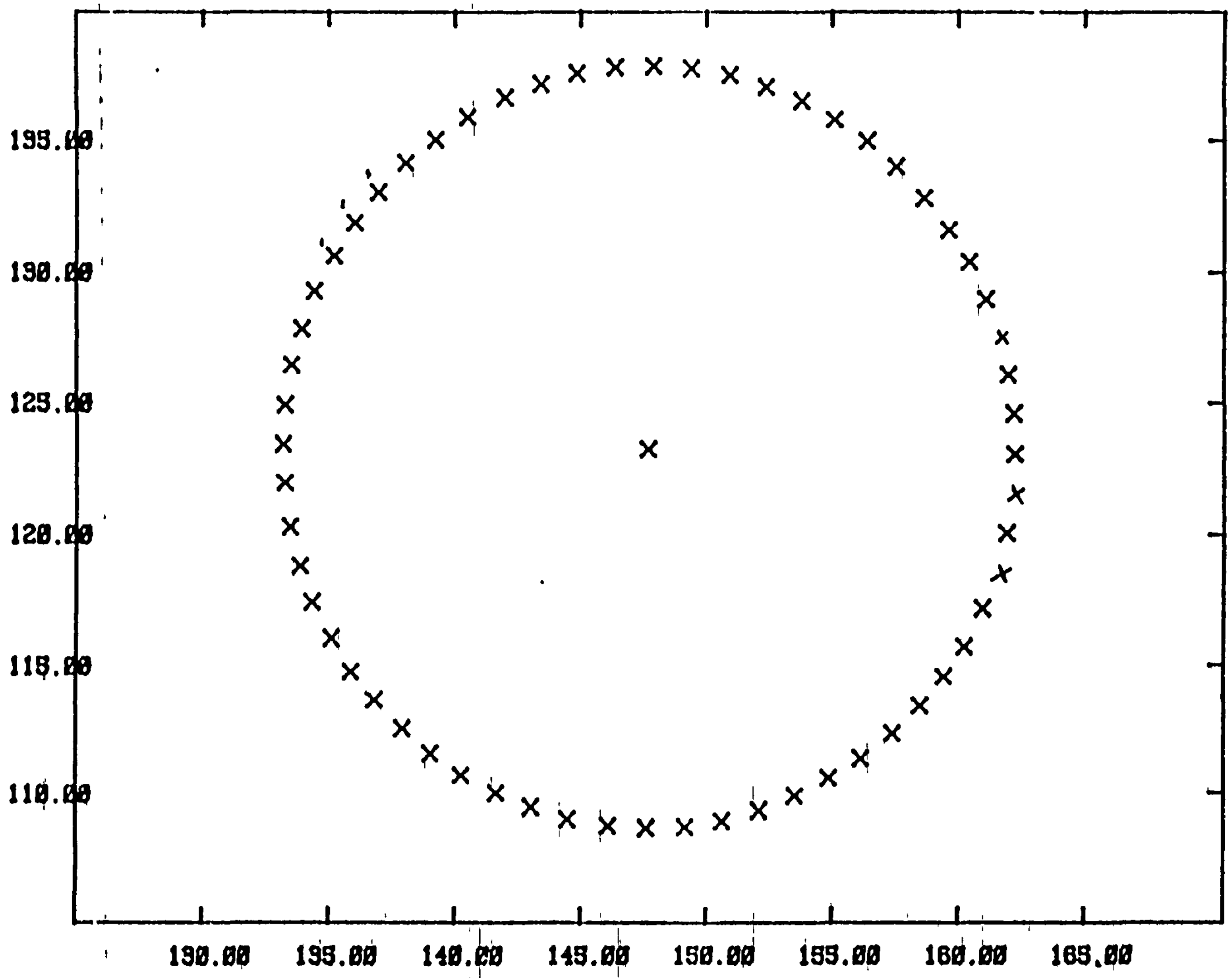
75



POSITION #1 S.D.= 2.023%

18-A-01 F2.8 +1.6M 2 K=.339.317.363.302 10% 0°C

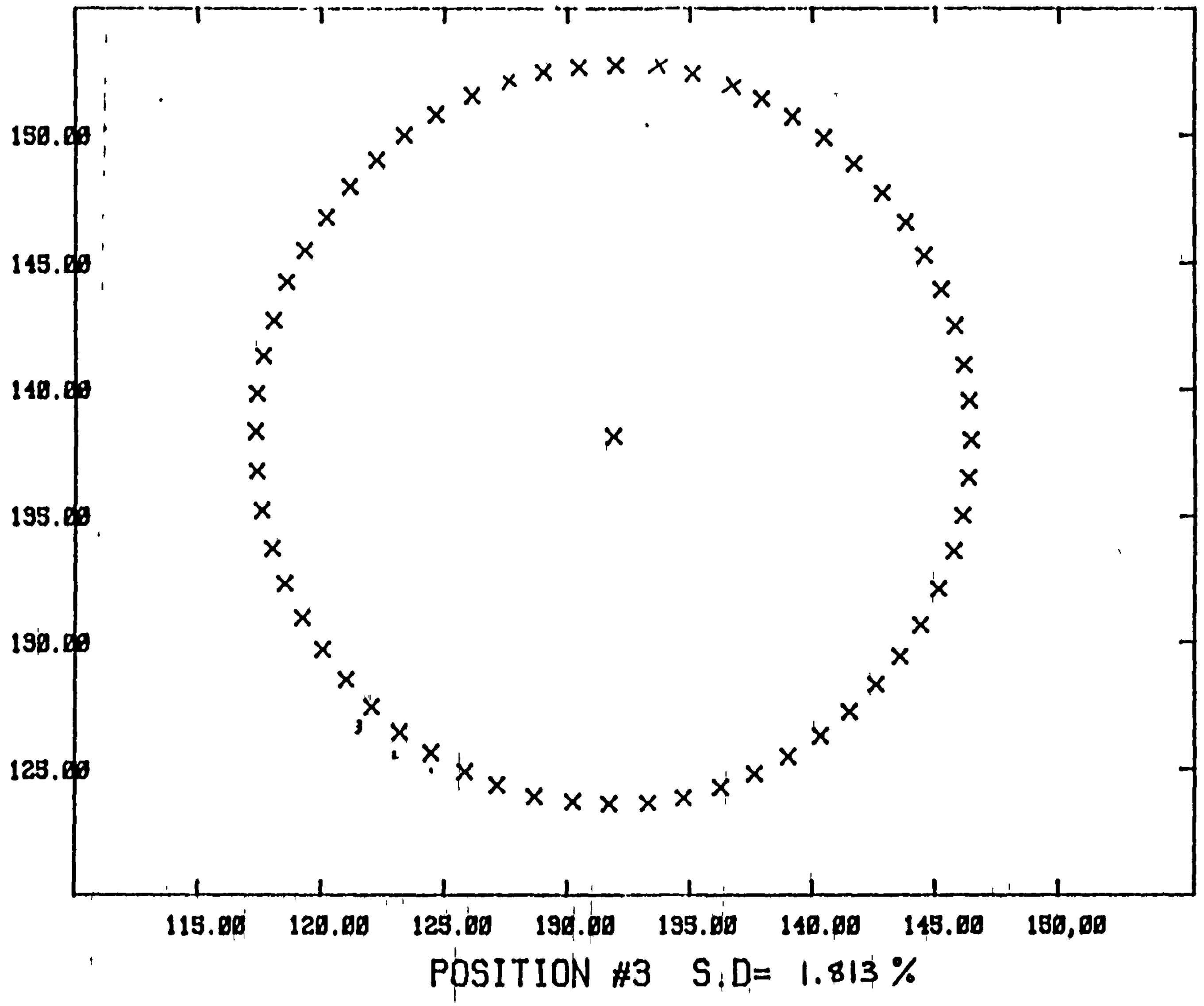
TR81-04



POSITION #2 S.D= 2.183 %

18-A-02 F2.8 ØM 2 K=.29.226.347.27 10% Ø°C

TR81-04



18-A-03 F2.8 -1.1M 2 K=.254.294.316.284 10% 0°C

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TR81-04

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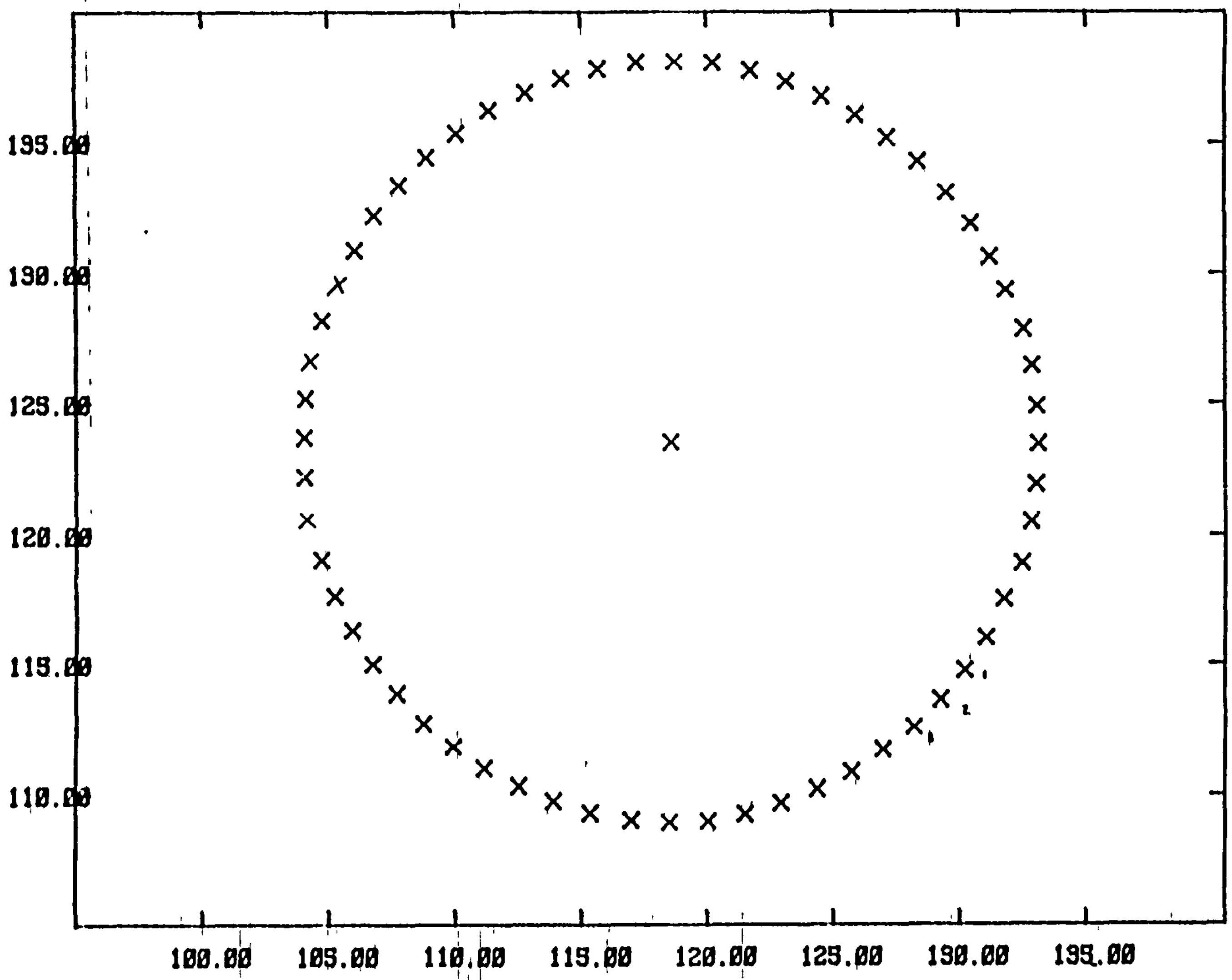

POSITION #4 S.D= 3.150 %

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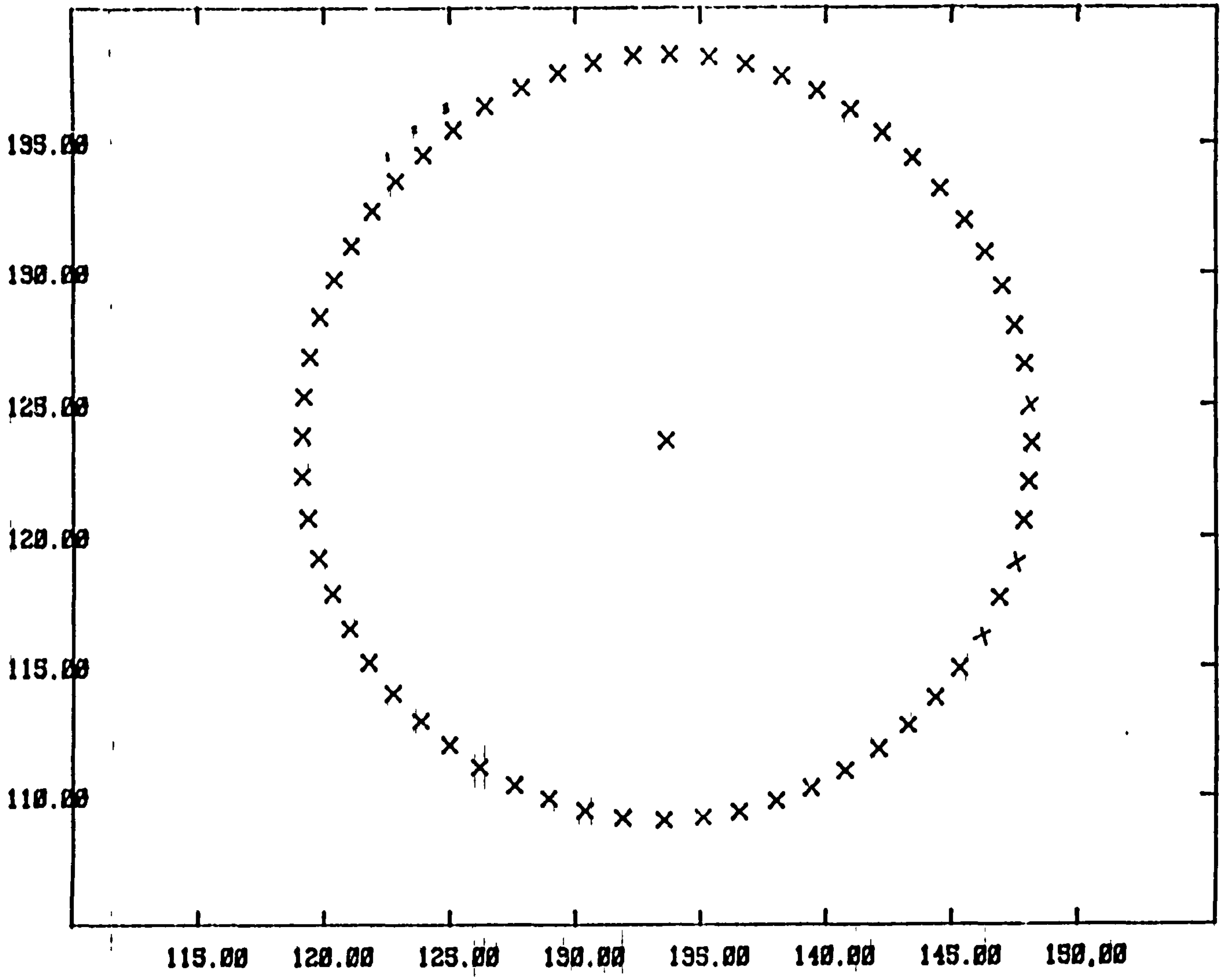
18-A-04 F2.8 -.8M 2 K=.262.303.362.262 10% 0°C



CENTER S.D= 1.992%

18-A-05 F2.8 ØM 2 K=.288.276.38.258 10% Ø°C

TR81-04

17 July 1981

DISK 1B-A   Track data file TDATA01

	Coarse	Fine	Track	
NDROI	1.0	1.0	64.0	
Integration delay	.1140E+00	.4574E+00	.1344E-02	
Thresholds	.1036E+06	.9190E+05	.735_E+06	
Constants	.33900	.31700	.36300	.30200
Displacements	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star max.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.173	39.518	.2082E+05	2.755	137.5	123.0 *	137.5397	123.3343	.1824E 02	.2781E-01
.116	45.734	.1946E+05	2.770	139.0	123.0	139.0920	122.9785	.8432E 03	.8720E 03
.150	52.033	.1129E+05	2.539	140.5	122.5	140.4554	122.4150	.4811E-03	.4931E 03
.215	58.378	.2080E+05	2.805	142.0	122.0	141.8001	121.7923	.7467E-03	.1025E-02
.223	64.625	.1190E+05	2.787	143.0	121.0	143.0449	120.9278	.1023E 02	.7102E-03
.223	70.895	.2434E+05	2.337	144.0	120.0	144.2211	119.9364	.5012E-03	.1052E-02
.158	1.778	.1481E+05	2.708	145.5	119.0 *	145.3334	118.7791	.1204E 01	.3209E-02
.175	8.150	.1853E+05	2.742	146.0	117.5 *	146.2901	117.5635	.8158E-02	.2464E-01
.237	14.365	.3342E+05	2.936	147.0	116.0	147.1032	116.3560	.1962E+00	.2388E+00
.024	20.735	.1996E+05	2.783	148.0	115.0	147.7877	114.9100	.5557E-03	.8227E-03
.114	26.977	.1691E+05	2.702	148.0	113.5	148.2813	113.5188	.9015E-03	.6889E-03
.187	33.257	.2418E+05	2.859	149.0	112.0 *	148.6870	111.9927	.5191E-02	.4817E-02
.130	39.543	.1220E+05	2.614	149.0	110.5	148.8375	110.5348	.3821E-02	.2299E-02
.170	45.833	.1183E+05	2.794	149.0	109.0	148.9607	109.0014	.5277E-03	.7175E-03
.175	52.087	.2442E+05	2.685	149.0	107.5	149.8537	107.5133	.7575E-03	.7498E 03
.201	58.365	.1722E+05	2.720	148.5	106.0	148.4213	106.0794	.9404E-03	.2622E 01
.170	64.649	.1643E+05	2.690	148.0	104.5	148.2266	104.5738	.2221E 02	.4494E 02
.080	70.891	.1905E+05	2.740	147.5	103.0	147.2526	103.0994	.7442E-03	.5665E-03
.112	1.709	.2105E+05	2.797	147.0	102.0	146.1978	101.7368	.9472E 03	.4265E-03
.187	8.168	.1936E+05	2.695	146.0	100.5	146.0584	100.4462	.1407E-02	.1115E 02
.206	14.364	.2092E+05	2.811	145.0	99.0	145.0737	99.2361	.1021E-02	.8904E-03
.237	20.725	.2829E+05	2.831	144.0	98.0	144.0158	98.2638	.5851E 01	.9201E-01
.125	26.970	.1513E+05	2.846	143.0	97.0	142.8111	97.2636	.1041E-02	.8016E 03
.201	33.232	.1504E+05	2.628	141.5	96.5	141.5437	96.4933	.7021E 03	.1125E 02
.274	39.536	.2549E+05	2.844	140.0	96.0	140.2053	95.8358	.9312E 03	.8504E-03
.161	45.825	.2313E+05	2.839	139.0	95.0	138.7499	95.2345	.1052E 02	.4710E 03
.161	52.103	.1690E+05	2.753	137.5	95.0	137.2105	94.9207	.8423E-03	.7645E 03
.077	58.372	.1475E+05	2.758	136.0	95.0	135.8727	94.7072	.4291E-03	.4317E-03
.108	64.635	.1260E+05	2.662	134.0	94.5	134.2549	94.5934	.1237E 02	.1713E 02
.128	70.884	.1504E+05	2.792	133.0	95.0	13[illegible].0154	94.7255	.1140E-02	.4451E 03
.15[illegible]	1.795	.1047E+05	2.741	131.0	95.0	[illegible]	94.974[illegible]	[illegible]	[illegible]
.156	8.170	.2547E+05	2.743	130.0	95.5 *	[illegible]	[illegible]	[illegible]	.1014E 01
[illegible]	14.370	[illegible]	[illegible]	[illegible]	96.0 *	[illegible]	[illegible]	.1170E 01	[illegible]
.161	20.71[illegible]	.1444E+05	2.690	127.0	96.5	[illegible]	97.2[illegible]	[illegible]	[illegible]
.147	2[illegible]	.1003E+05	2.707	126.0	97.5	[illegible]	97.4[illegible]	[illegible]	[illegible]

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.1	33	1E+0	2.	5	.5	1 [illegible]19	[illegible]8.4	[illegible]4E-0	.3[illegible]03
.184	39.520	.2225E+05	2.594	123.5	99.5	123.4791	99.5000	.1469E-02	.1494E 02
.187	45.814	.1092E+05	2.718	122.5	101.0 *	122.5274	100.7221	.2051E 02	.1584E 02
.173	52.115	.1959E+05	2.830	122.0	102.0	121.7486	102.0048	.7275E-03	.9797E 01
.153	58.456	.2061E+05	2.794	121.0	103.0	121.0532	103.2704	.5559E 03	.4570E-01
.195	64.650	.1001E+05	2.739	120.5	105.0	120.5046	104.7411	.7627E 03	.96[illegible]
.189	70.375	.2132E+05	2.782	120.0	106.0	120.13[illegible]	106.2145	.9194E 03	.0747E 03
.254	1.005	.2874E+05	2.825	120.0	108.0	119.9159	107.8242	.2113E 01	.2634E 01
.142	8.176	.1034E+05	2.736	120.0	109.5 *	119.1521	109.3928	.4545E-02	.104[illegible] 01
.130	14.376	.1750E+05	2.748	120.0	111.0	119.9954	110.8437	.4842E-03	.1428E 02
.184	20.730	.1667E+05	2.715	120.0	112.5 *	120.2077	112.3529	.1256E-02	.1171E-02
.234	26.973	.2197E+05	2.756	120.5	114.0	120.5955	113.8237	.1735E-01	.3414E 01
.171	33.263	.2013E+05	2.768	121.0	115.0	121.1562	115.1951	.4634E-03	.1104E 02
.234	39.538	.1508E+05	2.669	122.0	116.5	121.1740	116.5432	.7226E-03	.7254E 03
.206	45.835	.2422E+05	2.802	123.0	118.0 *	1[illegible]7079	117.8518	.1400E-01	.3002E-01
.161	52.114	.1744E+05	2.676	123.5	119.0	12[illegible]32	118.9726	.5139E 03	.3444E 03
.213	58.383	.2433E+05	2.807	125.0	120.0 *	124.7048	120.0286	.1145E-02	.2541E 02
.234	64.635	.124[illegible]E+05	2.768	126.0	121.0	125.7187	120.9925	.4763E-03	.3504E-04
.195	70.866	.2017E+05	2.779	127.0	122.0	127.2310	121.8825	.7077E-03	.91[illegible] 04
.170	1.784	.1118E+05	2.527	129.5	122.5	12[illegible].6649	122.5423	.9146E 03	.3005E 04
.156	8.130	.1940E+05	2.753	130.0	123.0	130.1153	123.0597	.4632E-03	.5460E 01
.125	14.362	.5982E+04	2.609	131.5	123.5	131.4597	123.4451	.1461E-02	.1091E-03
.217	20.732	.3733E+05	2.876	133.0	124.0	133.0249	123.5298	.1448E+00	.2017E+00
.276	26.984	.1745E+05	2.747	134.5	124.0	134.4994	123.7592	.1016E 02	.6444E-03
.189	33.259	.2231E+05	2.640	136.0	123.5	136.0909	123.6206	.4445E-03	.7842E-03

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	1	2	3	4	5	6
0	[illegible]	.00244	.00105	[illegible]	[illegible]	.00916
1	.00819	[illegible]	.00985	.00140	[illegible]	[illegible]
2	[illegible]	-.00385	-.01712	[illegible]	.00517	.01157
3	[illegible]	[illegible]	[illegible]	[illegible]	.01476	[illegible]
4	.02007	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	.00947	.02286	.00604	[illegible]	-.01707	[illegible]
6	[illegible]	.01385	-.00906	[illegible]	[illegible]	.01243
7	-.01004	-.00707	-.01528	[illegible]	.01120	-.01094
8	.01183	.00414	.00331	[illegible]	.00700	[illegible]
9	-.00865	.02375	.01504	-.12472	.02891	.01198

o= 134.4045 ,o= [illegible] rms 14.57[illegible] std.dev.= [illegible]

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	3	1	6	9	21	20	0

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delta ri

	1	2	3	4	5	6
0		-.00346	-.00463	.02344	.02575	.00492
1				-.00056	.01998	-.00901
2	-.01411	-.00364	-.01650	-.00251	.00675	.01396
3	-.03004	-.00119	.01943		.01690	-.00932
4	-.01687	.03903	-.01974	-.02537	.01857	-.02735
5	.01148			-.01151	-.01678	.00956
6	.02815	.01252	-.01095	.03299	.02737	.00087
7			-.02044	-.01770		-.01736
8	-.01859		-.00396	-.00078	-.01539	.02049
9	-.01631	-.03135	.00754		.02101	-.01879

u= 134.4021   v0= 109.1745   r0= 14.56322575   std.dev.= .02331

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	0	4	8	20	15	12

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DISK 18-A track data file TD01002

	Coarse	Fine	Track	
NORM	1.0	1.0	64.0	
Integration delay:	.1170E+00	.4564E+00	.1344E-02	
Thresholds:	.1038E+06	.9190E+05	.7352E+06	
Constants:	.29000	.22600	.34700	.27000
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.013	39.568	.7310E+04	2.598	135.0	130.5	135.2066	130.6167	.3654E-03	.6647E-03
.133	45.821	.2774E+05	2.708	136.0	132.0	136.0195	131.8950	.8132E-03	.1075E-02
.072	52.115	.1239E+05	2.673	137.0	133.0	136.9532	133.0278	.3146E-03	.3546E-03
.043	58.390	.2178E+05	2.669	138.0	134.0	138.0170	134.1197	.4958E-03	.7720E-03
.015	64.664	.1947E+05	2.650	139.0	135.0	139.1964	135.0336	.5966E-03	.5720E-03
.139	70.877	.2331E+05	2.714	140.5	136.0	140.4863	135.9016	.8155E-03	.8104E-03
.097	1.794	.1427E+05	2.612	142.0	136.5	141.9769	136.6352	.8478E-03	.6921E-03
.072	8.188	.1014E+05	2.703	143.5	137.0	143.4102	137.1420	.5339E-03	.6701E-03
.060	14.380	.1989E+05	2.597	145.0	137.5	144.8505	137.5697	.6691E-03	.8610E-03
.057	20.724	.1885E+05	2.700	146.5	138.0	146.3402	137.7730	.4382E-03	.4538E-03
.077	26.972	.2310E+05	2.708	148.0	138.0	147.6849	137.8307	.6912E-03	.6564E-03
.027	33.257	.1930E+05	2.688	149.5	138.0	149.3789	137.7379	.6920E-03	.7574E-03
.125	39.567	.1834E+05	2.590	151.0	137.5	150.9704	137.4924	.8732E-03	.1000E-02
.105	45.022	.9504E+04	2.706	152.5	137.0	152.3532	137.0503	.6201E-03	.2347E-03
.086	52.110	.1460E+05	2.573	154.0	136.5	153.7890	136.5230	.5987E-03	.7040E-03
.153	58.384	.2743E+05	2.715	155.0	136.0	155.0468	135.8101	.5397E-03	.5794E-03
.046	64.671	.1744E+05	2.686	156.5	135.0	156.3501	134.9761	.1993E-03	.5056E-03
.094	70.884	.1755E+05	2.695	157.5	134.0	157.5230	134.0023	.6375E-03	.4633E-03
.105	1.812	.1137E+05	2.673	158.5	133.0	158.6149	132.8277	.5913E-03	.3075E-03
.061	8.162	.2350E+05	2.577	159.5	131.5	159.5994	131.6366	.4756E-03	.1718E-03
-.013	14.373	.1039E+06	2.531	160.5	130.5	160.4173	130.4059	.5798E-03	.2414E-03
.091	20.731	.1196E+05	2.719	161.0	129.0	161.0674	128.9858	.2875E-03	.5438E-03
.046	26.959	.2689E+05	2.608	161.5	127.5	161.5912	127.6059	.4639E 03	.5916E-03
.008	33.272	.2626E+05	2.723	162.0	126.0	161.9628	126.0859	.1770E-01	.3109E-01
.069	39.552	.1567E+05	2.639	162.0	124.5	162.1733	124.6105	.2319E 02	.6044E 02
.043	45.022	.2006E+05	2.680	162.0	123.0	162.2160	123.0500	.6044E-03	.6202E 03
.122	52.094	.1911E+05	2.640	162.0	121.5	162.1430	121.6185	[illegible]	[illegible]
.133	58.300	.2979E+05	2.737	162.0	120.0	161.8771	120.0671	.8927E 02	[illegible]
.074	64.761	.1701E+05	2.606	161.5	118.5	161.5306	118.6622	.1760E 02	.6441E 02
.112	70.852	.1349E+05	2.700	161.0	117.0	160.9290	117.1007	.9424E 01	.1029E 02
.150	1.791	.2637E+05	2.747	160.0	116.0 *	[illegible]	115.7414	.2234E 01	[illegible]
.008	8.167	.1217E+05	2.524	158.5	114.5	[illegible]	114.5404	.1031E 02	[illegible]
.131	[illegible]	.1317E+05	2.716	158.5	113.5	[illegible]	113.4015	.7301E 01	[illegible]
.105	[illegible]	.1300E+05	2.747	157.5	112.5	[illegible]	[illegible]	[illegible]	[illegible]
.038	26.962	.2150E+05	2.612	156.0	111.5	156.1064	111.3707	.4519E 01	.4400E 01

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.0[illegible]	33.[illegible]	[illegible]7E+0[illegible]	2.[illegible]	[illegible]	[illegible].5	1[illegible]116	[illegible]10.5[illegible]	[illegible]E-0[illegible]	.36[illegible]02
.105	37.546	.1715E+05	2.730	153.5	110.0	153.4910	109.9193	.6919E 03	.5625E 03
.136	45.839	.1495E+05	2.630	152.0	109.5	152.0566	109.3665	.4643E 03	.4987E-03
.105	52.106	.1029E+05	2.713	150.5	109.0	150.5652	108.9479	.5891E 03	.9157E 03
.108	58.395	.1047E+05	2.702	149.0	109.0	149.1219	108.7601	.9954E 03	.3666E-03
.116	64.653	.1412E+05	2.635	147.5	103.5	147.5092	108.7020	.3285E-03	.8000E 03
.105	70.880	.1037E+05	2.716	146.0	109.0	147.0820	108.7890	.3546E 03	.3477E 03
.114	1.738	.9414E+04	2.717	144.5	109.0	144.4734	109.0299	.5714E-03	.2179E-03
.130	8.178	.1771E+05	2.608	143.0	109.5	142.9978	109.4774	.7342E-03	.2605E 03
.116	14.394	.1777E+05	2.711	141.5	110.0	141.6104	110.0134	.3013E-03	.4277E-03
.057	20.755	.1286E+05	2.644	140.0	111.0 *	140.2473	110.7091	.[illegible]739E 01	.8445E 02
.100	26.992	.2242E+05	2.602	139.0	111.5	139.0[illegible]	111.5640	.6636E-03	.1534E 01
.144	33.254	.1375E+05	2.592	138.0	112.5	137.6982	112.5207	.6670E-03	.3084E-03
.130	39.540	.2020E+05	2.641	137.0	113.5	1[illegible].8071	113.6381	.5693E 03	.5976E 03
.070	45.812	.1545E+05	2.659	136.0	115.0	1[illegible]778	114.7664	.9565E 03	.44[illegible]E 04
.164	52.099	.2185E+05	2.770	135.0	116.0	135.0955	116.0486	.7969E-03	.5894E-03
.206	58.376	.1153E+05	2.676	134.5	117.5	134.3244	117.3910	.6248E 02	.6450E-02
.116	64.647	.1330E+05	2.672	134.0	119.0 *	133.8398	118.7744	.2039E-02	.4328E-02
.175	70.000	.1474E+05	2.689	133.5	120.5 *	133.4348	120.3003	.2424E-02	.1794E 02
.161	1.801	.2160E+05	2.726	133.0	122.0	133.2179	121.9319	.7041E 03	.1022E 02
.120	8.185	.2340E+05	2.638	133.0	123.5	133.1517	123.4484	.1088E-01	.7789E-02
.150	14.386	.9664E+04	2.700	133.0	125.0	133.2483	124.9147	.5148E-03	.5642E-03
.128	20.721	.8752E+04	2.565	133.5	126.5	133.4908	126.4413	.3618E-03	.3831E 03
.243	26.949	.2707E+05	2.727	134.0	128.0	133.9022	127.8498	.5653E-03	.5507E-03
.173	33.257	.1174E+05	2.741	134.5	129.5 *	134.4068	129.2909	.1014E-01	.1461E-01

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	1	2	3	4	5	6
0	-.05478	-.02709	-.03060	.00239	-.02946	.00332
1	.00328	-.02172	.03920	.02307	.02011	.02285
2	.03327	.00140	.04074	-.00123	.00909	.00153
3	-.04086	-.00414	.03053	-.01556	-.00323	-.01907
4	-.02291	.04305	-.02518	.01011	.01219	.00724
5	.01524	.02501	.00106	.01667	-.01071	-.01104
6	.02190	-.00421	.01504	.00422	-.00768	[illegible]
7	.02782	-.00143	.01567	.03374	.00344	[illegible]
8	.02735	.00451	-.02965	.04737	.00948	.01119
9	-.01408	-.00477	-.00946	.00603	-.01318	[illegible]

x0= 147.7020   y0= 123.2533   r0= 14.55041160   std.dev.= .02263819

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	5	6	14	12	22	0

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delta ri

	1	2	3	4	5	6
0	.05227	-.02477	-.02849	-.00051	-.02680	.00475
1	-.00211	-.02077	.03993	.02359	.02042	.02298
2	.03322	.00118	.04039	-.00171	.00851	.00087
3	-.04158	-.00490	.02976	-.01632	-.00395	
4	-.02348	-.04351	-.02552		.01236	-.00749
5		.02556	.00183	.01776	-.00949	-.00272
6	-.02023	-.00231	.01716	.00655	-.00414	-.00094
7	.02973	.00165	.01089		.01108	-.01776
8	.02377	.00012	-.02202	.05070	.01306	.01470
9	-.01076		-.00727	.00908	-.01029	

x0= 147.7049 y0= 123.2544 r0= 14.55698395 std.dev.= .02182580

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	2	3	2	15	11	21	6

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DISK 18-A Track data file ...1A03

	Coarse	Fine	Tracl
NDROI	1.0	1.0	64.0
Integration delay	.1160E+00	.4564E+00	.1344F-02
Thresholds	.229[illegible]E+06	.9130E+05	.7352F+06

Constants	.25400	.29400	.31600	.28400
Displacements	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y	position X	position Y	standard deviation X	standard deviation Y
.248	20.692	.1740E+05	2.787	124.5	125.5	124.4272	125.6637	.5771E-03	.5764E-03
.209	26.955	.9681E+04	2.619	123.0	126.5 *	123.1551	126.4721	.2180E-01	.3700E-02
.217	33.243	.2582E+05	2.746	122.0	127.5	122.0177	127.4514	.9055F-02	.1447F-01
.201	39.504	.1362E+05	2.695	121.0	128.5	120.9763	128.5261	.5314F-03	.5401E-03
.248	45.825	.1940E+05	2.769	120.0	129.5	120.0173	129.7310	.7302E-03	.3485E-03
.153	52.107	.1888E+05	2.609	119.0	131.0 *	119.1839	130.9822	.9902F-02	.6113F-02
.192	58.364	.1232F+05	2.788	118.5	132.5	118.5078	132.3499	.4710E-03	.8401E-03
.220	64.646	.1927E+05	2.776	118.0	133.5	117.9996	133.7431	.1073E-02	.5362F-03
.187	70.888	.1825E+05	2.767	117.5	135.0	117.5937	135.2148	.3422E-03	.5500E-03
.237	1.791	.1108F+05	2.741	117.5	137.0 *	117.3554	136.8252	.2883E-02	.9102E-02
.229	8.186	.9778E+04	2.719	117.5	138.5	117.3210	138.3824	.9386E-03	.4899E-03
.327	14.367	.2592E+05	2.762	117.5	140.0	117.3863	139.8439	.3559E-03	.5477E-03
.248	20.722	.2182E+05	2.848	117.5	141.5	117.6230	141.3808	.1510E-01	.2949E-01
.187	26.965	.1453E+05	2.646	118.0	143.0 *	118.0725	142.7866	.1828E-02	.4681E-02
.229	33.257	.1466E+05	2.799	118.5	144.5 *	118.5840	144.2601	.1665E-02	.4882E-02
.195	39.513	.1853E+05	2.827	119.5	145.5	119.3159	145.5074	.5666E-03	.8270E-03
.178	[illegible].026	.1446F+[illegible]	2.617	120.0	147.0 *	120.1711	146.7907	.2233F-02	.6341F-02
.271	52.091	.2990E+05	2.644	121.0	148.0	121.1351	147.9660	.4672F-03	.1813F-02
.257	58.380	.1059E+05	2.644	122.5	149.0 *	122.2108	149.0263	.1147E-01	.8000F-02
.262	64.670	.2100F+05	2.680	123.5	150.0	123.3718	149.9955	.7749E-03	.4834F-03
.1[illegible]2	70.884	.1244F+05	2.623	124.5	151.0	1[illegible]4.[illegible]3	1[illegible]0.7786	.4173E-03	.7413E-03
.109	1.006	.2255F+05	2.698	126.0	151.5	126.1233	151.5082	.6602F-03	.5485E-03
.324	8.163	.2465E+05	2.712	127.5	152.0	127.5339	152.0351	.7818E-03	.8093F-03
.296	14.366	.1373E+05	2.666	129.0	152.5	129.0035	152.4355	.1778F-03	.5675F-03
.276	20.727	.1362F+05	2.728	130.5	152.5	130.4706	152.6291	.2819F-03	.7076E-03
.254	26.960	-.4390E+04	2.751	132.0	152.5	131.9554	152.6999	.3068F-02	.4343E-03
.282	33.241	.1384F+05	2.697	133.5	152.5	133.4099	152.6025	.7488E-03	.7745E-03
.271	39.533	.1000F+05	2.717	135.0	152.5	135.0782	152.3576	.4274F-03	.3911E-03
.296	45.834	.2569E+05	2.712	136.5	152.0	136.4593	151.9562	.1103F-02	.3486F-03
.201	52.105	.2390E+05	2.668	138.0	151.5	137.6992	151.4058	.5701E-03	.4477F-03
.203	58.364	.1176E+05	2.633	139.0	150.5	139.1059	150.2144	.4129[illegible]	.1657[illegible]
.276	64.645	.2038E+05	2.72[illegible]	140.5	150.0	140.457[illegible]	149.9[illegible]	[illegible]	[illegible]
.100	70.07[illegible]	.125[illegible]E+05	2.70[illegible]	141.5	149.0	141.[illegible]	148.007[illegible]	[illegible]	[illegible]
.[illegible]	1.7[illegible]	[illegible]	2.701	143.0	148.0 *	[illegible]	147.[illegible]	[illegible]	[illegible]
.[illegible]	8.17[illegible]	.9044E+04	2.550	143.5	146.[illegible]	14[illegible].7741	146.[illegible]	[illegible]	[illegible]

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.321	14.[illegible]	[illegible]	2.7[illegible]	144.[illegible]	[illegible].3	144.[illegible]	143.30[illegible]	[illegible]E-02	.117[illegible] 02
.377	20.723	.2840E+05	2.704	145.0	144.0	145.2073	143.9600	.5303F-03	.1017F-02
.217	26.962	.9170E+04	2.563	145.5	142.5	145.7671	142.5738	.4318F-02	.2900L-02
.304	33.249	.1190E+05	2.642	146.0	141.0	146.1065	141.0174	.5176E-03	.4097F-03
.257	39.547	.2110F+05	2.673	146.5	139.5	146.3293	139.5706	.4787E-03	.387[illegible] 03
.268	45.826	.2037E+05	2.669	146.5	138.0	147.4093	138.0557	.7784F-03	.2016F 03
.271	52.100	.1581F+05	2.656	146.5	136.5	147.3040	136.5465	.242[illegible]-02	.7734 02
.265	58.397	.2034E+05	2.623	146.0	135.0	146.0417	135.0123	.4717F-03	.4721I 03
.276	64.643	.1843F+05	2.711	145.5	133.5	145.[illegible]	133.63[illegible]	.4[illegible] 03	.[illegible] 03
.279	70.[illegible]	.27[illegible]	2.707	145.0	[illegible].0	145.0061	132.1515	.2064 02	.281[illegible]
.260	1.805	.1[illegible]	2.698	144.5	130.5	144.3709	130.7129	.8540 02	.2110I-01
.324	8.195	.1823E+05	2.731	143.5	129.5	143.5138	129.4657	.5707E-03	.6336I-03
.282	14.369	.1281E+05	2.755	142.5	128.5	142.5541	128.3260	.6005I-03	.5672I 03
.243	20.718	.1904F+05	2.769	141.5	127.0	141.4786	127.2258	.5134F 03	.5172F-04
.206	26.989	.1019E+05	2.655	140.5	126.5	140.3092	126.3012	.3090F-03	.3641I-04
.330	33.261	.2121E+05	2.675	139.0	125.5	138.9946	125.5048	.8581I-03	.4664F-03
.324	37.576	.1215E+05	2.701	137.5	125.0	137.6050	124.8231	.6442E-03	.5130I-03
.282	45.824	.1310E+05	2.731	136.5	124.5	137.2308	124.2904	.4891E-03	.5622F-03
.352	52.101	.2016E+05	2.716	134.3	124.0	134.7245	123.9149	.4816F-04	.8001E-03
.276	50.307	.2031F+05	2.760	133.5	123.5	133.2698	123.6963	.7942I-03	.1098L-02
.231	64.622	.1072E+05	2.721	131.5	123.5	131.7024	123.6526	.8553E-03	.5962I-03
.220	70.884	.1991E+05	2.768	130.5	123.5	130.2231	123.7199	.3004E-03	.7193F-03
.330	1.798	.2581E+05	2.702	128.5	124.0	129.6379	123.9509	.[illegible]E-03	.6053F 03
.327	8.193	.1367E+05	2.658	127.0	124.5	127.1407	124.3942	.3958F-03	.8747F-03
.268	14.359	.1533F+05	2.655	126.0	125.0	125.8251	124.9114	.4506F-03	.6477F 03

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delta ri

	1	2	3	4	5	6
0	-.00834	.02469	-.00464	-.01478	[illegible]	.01639
1	.01011	-.00470	.01484	.01322	-.01225	.01019
2	.04339	-.01046	.05686	-.01600	-.02348	-.02121
3	.02097	.01175	-.01654	.02343	-.01702	.00721
4	-.01510	.01002	-.01547	[illegible]	-.00578	.00924
5	-.01167	.02347	-.01583	.00781	.03589	.00240
6	.00918	.04737	-.01266	.00464	.00742	-.00841
7	-.01503	.00072	-.01474	.01788	.00211	-.01357
8	.02064	.01858	-.01490	.02147	-.00147	-.01366
9	-.01214	-.03673	-.01294	.02370	.00545	.01095

x0= 131.8547   y0= 138.1627   r0= 14.54760933   std.dev.= .01884822

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	2	2	9	29	17	0

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delta ri

	1	2	3	4	5	6
0	-.00543			-.01190	-.01146	.01915
1	.01278	-.00213	.01729	.01552	-.01012	.01016
2		.00006	.05826	-.01479	.02148	.01042
3		.01214	-.01635	.02343	-.01800	.00686
4	-.01558	-.01064	-.01421	.00784	-.00267	.00877
5		.02244	-.01686	.00682	.03495	.00152
6	.00840	.04669	-.01321	-.00506	.00716	-.00850
7	-.01494	.00099	-.01425		-.00120	-.01247
8	.02195	.02009	-.01320	-.01958	.00059	-.01149
9	-.00977	-.03422	-.01032	.02643	.00826	.01381

x0= 131.8552   y0= 138.1642   r0= 14.54666519   std.dev.= .01813333

HISTOGRAM DEVIATION >=

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	1	2	8	24	18	6

DISK 18-A   Track data file TDATA04

	Coarse	Fine	Track	
NDROI	1.0	1.0	64.0	
Integration delay:	.1160E+00	.4564E+00	.1344E-02	
Thresholds:	.1036E+06	.9190E+05	.7357E+06	
Constants:	.27200	.30300	.36200	.26200
Displacements:	0.00000	0.00000	0.00000	0.00000

		dark	star	reference		position		standard deviation	
temp	angle	current	mag.	X	Y	X	Y	X	Y
.240	8.153	.1548E+05	2.692	130.0	115.0 *	130.2009	114.8000	.8556E-02	.72[illegible]E-02
.272	14.372	.1804E+05	2.750	129.5	113.5 *	129.2456	113.6800	.2168E-02	.1779E-01
.239	20.711	.1653E+05	2.664	128.0	112.5 *	128.1613	112.6159	.1665E-02	.1100E-01
.240	26.978	.2456E+05	2.709	127.0	111.5 *	126.9789	111.6785	.4352E-02	.2979E-01
.231	33.228	.1489E+05	2.686	125.5	111.0	125.7146	110.8520	.1012E-02	.9403E-03
.268	39.530	.2067E+05	2.733	124.5	110.0	124.3550	110.2262	.5062E-02	.5959E-02
.302	45.825	.2125E+05	2.722	123.0	109.5 *	122.9308	109.6936	.3671E-02	.2527E-01
.290	52.090	.1325E+05	2.774	121.5	109.5	121.4741	109.2946	.3892E-03	.9102E-03
.271	58.367	.1212E+05	2.723	120.0	109.0	119.9851	109.0367	.6209E-03	.7377E-03
.290	64.657	.9789E+04	2.768	118.5	109.0	118.4609	108.9941	.6821E-03	.1077E-02
.279	70.080	.1258E+05	2.739	117.0	109.0	116.9409	109.0478	.4231E-03	.1003E-02
.233	1.802	.1482E+05	2.718	115.5	109.5	115.3302	109.3452	.6159E-03	.6671E-03
.217	8.169	.2509E+05	2.762	114.0	110.0	113.8906	109.7859	.1910E-02	.2474E-02
.229	14.369	.8741E+04	2.697	112.5	110.5	112.5116	110.3205	.6264E-03	.4271E-03
.237	20.715	.1896E+05	2.702	111.0	111.0 *	111.1336	111.0080	.5030E-02	.9547E-02
.304	26.552	.2022E+05	2.771	110.0	112.0	109.9103	111.8590	.1593E-02	.2360E-02
.239	33.245	.1285E+05	2.734	108.5	113.0 *	108.7323	112.7867	.1961E-01	.1339E-02
.302	39.533	.1979E+05	2.737	107.5	114.0	107.6781	113.9150	.1142E-02	.4049E-03
.245	45.807	.1781E+05	2.708	106.8	115.0	106.7290	115.0285	.5030E-03	.9465E-03
.271	52.094	.1302E+05	2.743	106.0	116.5	105.9130	116.3808	.5455E-03	.4639E-03
.257	58.381	.1714E+05	2.808	105.5	117.5	105.2173	117.6961	.2378E-03	.4444E-03
.229	64.627	.1779E+05	2.692	104.5	119.0	104.7065	119.0570	.5840E-03	.8525E-03
.233	70.884	.1270E+05	2.720	104.5	120.5	104.2768	120.5710	.6721E-03	.5277E-03
.304	1.805	.2447E+05	2.718	104.0	122.0	104.0509	122.2275	.4903E-03	.6515E-03
.248	8.166	.2170E+05	2.775	104.0	123.5	104.0271	123.7269	.4972E-03	.2265E-03
.299	14.370	.1300E+05	2.693	104.0	125.0	104.0918	125.2299	.7841E-03	.5395E-03
.321	20.714	.9067E+04	2.753	104.5	126.5	104.3591	126.6804	.4204E-03	.4423E-03
.380	26.987	.2227E+05	2.752	104.5	128.0	104.7523	128.1845	.4835E-03	.5090E-03
.277	33.241	.1750E+05	2.794	105.5	129.5	105.3117	129.5721	.4494E-03	[illegible]
.234	39.534	.1832E+05	2.645	106.0	131.0	106.0343	130.9113	.1281E-02	.7605E-03
.375	45.780	.2500E+05	2.741	107.0	132.0 *	106.8[illegible]	132.2248	.3594E-02	.4[illegible]E-02
.327	[illegible]	.2276E+05	2.754	108.0	133.5 *	107.8087	133.4087	.2564E-02	.1615E-01
.257	58.373	[illegible]	[illegible]	[illegible]	134.5	[illegible]	134.4570	[illegible]	[illegible]
.316	64.721	[illegible]	2.721	110.0	[illegible]	110.0004	[illegible]	[illegible]	[illegible]
.307	70.852	[illegible]	2.720	111.5	136.0	[illegible]	[illegible]	.6684E-03	.7124E-04

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.26[illegible]	1.[illegible]	.[illegible]E+0[illegible]	2.7[illegible]	1[illegible]	[illegible]0 *	11[illegible]05	[illegible]6.90	[illegible]	.2[illegible]-02
.302	8.180	.1707E+05	2.695	114.5	137.5	114.2667	137.4602	.7413E-03	.4816E-03
.310	14.369	.2043E+05	2.719	115.5	138.0	115.7003	137.8279	.4553E-03	.6525E-03
.290	20.716	.2026E+05	2.721	117.5	138.0 *	117.[illegible]	138.0745	.2987E-02	.4071E-02
.307	27.000	.1202E+05	2.693	118.5	138.0	118.7[illegible]	138.0071	.7860E-03	.1487E-03
.262	33.240	.2003E+05	2.720	120.5	138.0 *	120.2[illegible]49	138.0523	.2143E-02	.4444E-02
.262	39.532	.2142E+05	2.711	121.5	138.0	121.7473	137.7565	.6075E-03	.6048E-03
.274	45.832	.1552E+05	2.665	123.0	137.5	123.1871	137.3455	.4170E-03	.5863E-03
.282	52.095	.1169E+05	2.696	124.5	137.0	124.5758	136.7787	.8634E-03	.1146E-02
.352	58.370	.2661E+05	2.747	126.0	136.0	125.9211	136.0780	.4741E-03	.8986E-03
.229	64.643	.2142E+05	2.682	127.0	135.0	127.1541	135.2290	.5369E-03	.5914E-03
.265	70.898	.2473E+05	2.746	128.5	134.0	128.3603	134.3048	.3352E-01	.4961E-01
.290	1.794	.1037E+05	2.724	129.5	133.0	129.4[illegible]8	133.0955	.7234E-03	.7050E-03
.400	8.178	.2336E+05	2.749	130.5	132.0	130.4457	131.9246	.6001E-03	.6134E-03
.293	14.371	.2522E+04	2.643	131.5	130.5 *	131.1958	130.6562	.8430E-02	.9076E-02
.375	20.721	-.1064E+04	2.719	132.0	129.5	131.8[illegible]	129.3504	.2210E-02	.3995E-03
.303	26.990	.6394E+04	2.836	132.5	128.0	132.5367	127.8619	.2596E-02	.1804E-03
.279	33.256	.8404E+04	2.596	133.0	126.5	132.8571	126.4465	.5789E-03	.5455E-03
.318	39.534	.1123E+05	2.713	133.0	125.0	133.0736	124.9035	.4043E-03	.7159E-03
.310	45.839	.2091E+05	2.657	133.0	123.5	133.1120	123.4532	.3197E-03	.6074E-03
.352	52.007	.2210E+05	2.730	133.0	122.0	133.0372	121.9139	.7221E-03	.9177E-03
.350	58.365	.1227E+05	2.644	133.0	120.5	132.8201	120.4927	.5188E-03	.4521E-03
.302	64.654	.3761E+04	2.731	132.5	119.0	132.4531	118.9313	.9174E-03	.8252E-03
.313	70.877	.8975E+04	2.728	131.5	117.5	131.7469	117.5934	.9127E-03	.4075E-03
.327	1.812	.2704E+05	2.684	131.0	116.0	131.0417	116.0561	.9345E-03	.1657E-02

delta ri

	1	2	3	4	5	6
0	.00841	-.00847	-.00418	-.00240	.01819	-.02750
1	-.02850	-.00824	.02406	-.00335	.03227	.00685
2	.02638	-.01472	.01413	-.01092	.01302	-.02782
3	.01806	.02469	.00809	.00175	.02856	.00795
4	.02752	.00420	-.01087	.00443	-.00702	-.03057
5	.02392	.02902	.02034	-.00788	.03186	-.02921
6	.00257	.00696	.03286	-.01537	.04467	.00716
7	.00121	-.01914	-.02082	-.05001	.00050	-.01953
8	-.01097	-.05376	-.06377	.07585	.04057	.02534
9	.00075	.01746	.03185	.06802	-.08339	.00479

[illegible]= 118.5550 v0= 123.5470 r0= 14.55650520 std.dev.= [illegible]

HISTOGRAM DEVIATION >= e

e:	.05	.04	.03	.02	.01	0.00	bad points
	6	2	6	14	11	21	0

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delta ri

	1	2	3	4	5	6
0	.00612				.01612	.02949
1		-.01001	.02241	-.00486	.03090	.00564
2	-.02744	-.01563	.01338	-.01351		-.02810
3	.01791	-.02469	.00822	.00199	.02892	.00801
4	-.02697	.00489	-.01821	.00513	-.00630	.02985
5	.02463		.02097		.03226	
6	.00286	.00714	.03292	-.01540	.04445	.00679
7	-.00175	-.01901	-.02165	-.05180		-.04084
8	-.01242	-.05535	-.06548	.07401	.02863	.02470
9	-.00137	.01528	.02961	.08574	-.08568	.00249

θ0= 118.5563   φ0= 123.5462   r0= 14.55729580   std.dev.= .03150113

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	6	2	4	13	11	15	9

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DISK 18-A   Track data file TDAT005

	Coarse	Fine	Track
NDROI	1.0	1.0	64.0
Integration delay:	.1160E+00	.4544E+00	.1344E-02
Thresholds:	.2298E+06	.9190E+05	.7352E+06

Constants:	.20000	.27600	.30000	.25000
Displacements:	0.00000	0.00000	0.00000	0.00000

temp	angle	dark current	star mag.	reference X	reference Y		position X	position Y	standard deviation X	standard deviation Y
.184	52.065	.2261E+05	2.546	123.0	133.5		122.8489	133.5199	.8514E-03	.4442E 03
.156	58.262	.9014E+04	2.446	124.0	134.5		123.9122	134.5409	.2966E-03	.4061E 03
.091	64.632	.2421E+05	2.510	125.0	135.5		125.1195	135.4875	.4737E-03	.5021E-03
.142	70.870	.1371E+05	2.589	126.5	136.5		126.3944	136.3539	.4058E-03	.5076E 03
.167	1.798	.1349E+05	2.596	128.0	137.0	*	127.6520	137.0276	.2356E-01	.6104E-02
.178	8.149	.1800E+05	2.559	129.5	137.5	*	129.3003	137.5880	.3470E-03	.1060E-02
.164	14.389	.2065E+05	2.570	130.5	138.0		130.7296	137.9620	.6295E-03	.3992E-03
.254	20.727	-.3567E+04	2.659	132.5	138.0	*	132.3121	138.2170	.8597E-01	.4509E 02
.226	26.990	.2136E+05	2.606	134.0	139.0	*	133.7495	138.2552	.2530E-02	.1350E-02
.192	33.241	.1062E+05	2.656	135.5	138.0		135.3315	138.1731	.1414E-02	.1812E-02
.198	39.558	.2400E+05	2.610	137.0	138.0	*	136.7941	137.9126	.1027E-01	.1385E-02
.161	45.821	.1886E+05	2.505	138.0	137.5		138.2320	137.4712	.8578E-03	.3472E-03
.144	52.097	.1241E+05	2.594	139.5	137.0		139.6212	136.9245	.7167E-03	.8707E-03
.158	58.361	.2915E+05	2.667	141.0	136.0		140.9542	136.2378	.8464E-02	.1762E-01
.072	64.623	.2374E+05	2.503	142.0	135.5		142.2146	135.3838	.4173E-03	.7075E-03
.116	70.877	.9771E+04	2.420	143.5	134.5		143.4372	134.4190	.6270E-03	.4346E-03
.136	1.798	.1246E+05	2.596	144.5	133.0	*	144.5476	133.2445	.1450E-02	.1202E-01
.167	8.17	.2435E+05	2.630	145.5	132.0		145.4980	132.0343	.8673E-03	.1274E-02
.018	14.335	.1585E+05	2.575	146.5	131.0		146.2908	130.7907	.7052E-03	.6919E-03
.097	20.726	.1920E+05	2.515	147.0	129.5		146.9732	129.4760	.4077E-03	.5126E-03
.106	26.963	.2530E+05	2.607	147.5	128.0		147.4921	128.0078	.5677E 03	.4215E 03
.091	33.244	.1157E+05	2.441	148.0	126.5		147.8806	126.5658	.5041E-02	.2897E-02
.161	39.532	.1175E+05	2.575	148.0	125.0		148.0892	125.0326	.7053E-03	.1290E 02
.133	45.820	.2406E+05	2.508	148.0	123.5		148.1522	123.5572	.5050E-03	.2824E-03
.156	52.117	.2362E+05	2.569	148.0	122.0		148.0557	122.0424	.3691E-03	.1109E 02
.116	58.356	.1707E+05	2.439	148.0	120.5		147.8373	120.5866	.6914E 02	.6108E 02
.077	64.615	.1990E+05	2.573	147.5	119.0		147.4308	119.0748	.8166E-03	.9712E-03
.139	70.891	.2132E+05	2.563	147.0	117.5		146.8519	117.6855	.6793E-03	.5597E 03
.215	1.826	.2550E+05	2.620	146.0	116.0	*	146.0896	116.2216	.4901E-02	.5956E-02
.091	8.193	.1824E+05	2.591	145.5	115.0		145.2725	114.9482	.7311E-03	.8068E-03
.144	14.381	.2011E+05	2.612	144.5	114.0		144.3121	113.8055	.4159E 03	.9671E 03
.142	20.719	.1072E+05	2.573	143.0	113.0		143.2177	112.7006	.3394E 03	.2908E 03
.189	26.976	.3027E+05	2.633	142.0	112.0		142.0484	111.7905	.7150E 03	.7151E 03
.080	33.257	.1215E+05	2.580	140.5	111.0	*	140.7500	110.5903	.3391E 02	.1075E 02
.080	39.504	[illegible]	2.500	[illegible]	110.5		[illegible]	110.[illegible]	.4141E [illegible]	[illegible]

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.1[illegible]	4[illegible]	[illegible]E+0[illegible]	2.[illegible]	[illegible]	[illegible].0	1[illegible]399	[illegible]9.8[illegible]	[illegible]	.5[illegible]-03
.13?	52.117	.1707E+05	2.52?	136.5	10?.5	1?.5243	109.4164	.4489E 03	.533?E 0?
.1?1	58.384	.3414E+04	2.673	135.0	10?.0	1?5.0808	109.1800	.93??E-03	.73??E-03
.147	64.644	.1021E+05	2.652	133.5	109.0	133.5167	109.0898	.4864E-03	.?904E 03
.170	70.891	-.2419E+04	2.699	132.0	10?.0 *	131.8730	109.1624	.2450E-01	.6466E 0?
.196	1.834	.1771E+05	2.512	130.5	10?.5	1?0.?677	109.4418	.0730E 03	.5915E 0?
.170	?.178	.2350E+05	2.645	1??.0	110.0	1??.9?68	109.9412	.9??E 03	.71?8E 0?
.0?1	14.403	.8272E+04	2.437	127.5	110.5	127.5546	110.4320	.49?0F 03	.5?38E 0?
.091	20.771	.2043E+05	2.620	126.0	111.0	1??.1545	111.1118	.??0?F 0?	.8337F 0?
.212	26.?7?	.2054E+05	2.671	125.0	11?.0	1?4.9425	111.9741	.7327E-0?	.12??E 0
.116	33.275	.1517E+05	2.612	124.0	113.0	1??.7994	112.9?05	.9044F-03	.7??4 0?
.153	3?.565	.1997E+05	2.704	122.5	114.0	1??.7124	114.01?0	.6?64E 03	.615? 0?
.11?	45.843	.2045E+05	2.633	121.5	115.0 *	1?1.7496	115.175?	.3504E 0?	.?211E 0?
.153	5?.106	.1457E+05	2.541	121.0	116.5	120.?6??	116.47?9	.4260E-03	.?254E 03
.153	58.367	.2164E+05	2.636	1?0.5	118.0	1?0.?69?	117.6577	.9042E-03	.?2071 0?
.136	64.659	.2011E+05	2.611	119.5	119.0	119.7342	119.2168	.3918E-03	.7220E 03
.212	70.873	.1309E+05	2.620	119.5	120.5	119.3199	120.7158	.2872E-03	.9253E-03
.122	1.823	.1360E+05	2.544	119.0	122.5 *	119.0918	122.3496	.2693E-02	.3150E-01
.?34	8.164	.3079F+05	2.628	119.0	124.0	119.0097	123.8694	.6551E-03	.1185E 02
.150	14.365	.2056F+05	2.609	119.0	125.5	11?.1600	125.3345	.2092E-01	.2091F-01
.097	20.727	.1530E+05	2.576	119.5	127.0	119.3983	126.8388	.5921E-03	.6?3?F-02
.181	26.996	.1415E+05	2.595	120.0	128.5	119.8087	128.3386	.2716F-03	.7861F-03
.184	33.280	.2303F+05	2.653	120.5	130.0 *	120.3639	129.6979	.5598E-02	.2423E 01
.11?	39.545	.2090E+05	2.559	121.0	131.0	121.0634	131.0322	.7826E-03	.?424E 03
.150	45.832	.13??F+05	2.577	122.0	132.5	121.9133	132.3670	.1016F-02	.3311F 03

delta ri

	1	2	3	4	5	6
0	.01950	-.00072	-.01688	.02490	-.02139	.00343
1	.01342	.03960	.02129	.04120	.03125	-.00725
2	-.00752	-.00424	-.02531	.00513	-.02199	-.02192
3	-.01360	.01364	-.01176	.00711	-.01174	-.01201
4	-.01727	.00340	.01015	-.02272	-.02088	.00841
5	-.01336	.02700	.01615	.05081	.00442	-.01406
6	.00911	.00612	.02147	.05011	.01280	.04742
7	.00503	.04149	-.00793	.01121	-.00703	.02211
8	-.02716	-.01564	-.00514	.02404	.00940	-.04742
9	-.02472	-.00872	.00006	-.01729	-.02219	.00640

x0= 133.6029 y0= 123.6720 r0= 14.56180286 std.dev.= .02131811

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	1	4	4	15	16	20	0

delta ri

	1	2	3	4	5	6
0	.01918	-.00107	-.01725	.02451		.00[illegible]07
1	.01309		.02105	.04103		.00727
2	.00746		-.02504	.00[illegible]1		.0[illegible]131
3	-.01286	.01449	-.01079	.00717	-.01054	.01071
4	-.01587	.00409	.01973	.0[illegible]106	-.01915	.01046
5	.01154	.0[illegible]086	.01803	.0[illegible]20	.00630	.01218
6	.00727	.00792	.02[illegible]2		.01441	.04409
7	-.00357	.04[illegible]83	-.00749	-.01008	.00602	.02[illegible]50
8	-.02238	-.01458	.00568	.02447		-.04712
9		-.00871	-.00002		-.02241	.00220

x0= 133.6023 y0= 123.6733 r0= 14.56105137 std.dev.= .01992372

HISTOGRAM DEVIATION >= e

e=	.05	.04	.03	.02	.01	0.00	bad points
	0	4	2	11	17	17	9

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REPORT APPENDIX A

TEST PROCEDURE
FOR A
BREADBOARD STELLAR TRACKER SYSTEM

Ball No. 2332-101 Feb. 17, 1981

Prepared for
NASA-Marshall Space Flight Center

Contract No. 8-342[illegible]3

Prepared By:

J. C. Kollodge

J. C. Kollodge
Project Supervisor

Section 1
INTRODUCTION

This document defines the procedures that will be used to conduct the test program described in BASD's proposal No. P078 titled, "Test Program for Breadboard Stellar Tracker System."

The test that will be conducted are:

1. Inter-pixel Transfer Function
2. Small Field Pointing Accuracy
3. Large Field Pointing Accuracy
4. Rate Tracking Performance
5. Acquisition Sensitivity
6. Tracking Sensitivity
7. Tolerance to CID Defects

The accuracy tests of one through four and test seven will be conducted using a system of light deviating wedges to control the angle of a light beam eminating from a star simulator.

The wedge drive system allows linear deflection by counter rotating two wedges or conical deflection by rotating a single compound wedge. The angular change that is introduced will be determined by monitoring wedge rotation angle via a potentiometer geared to the wedge. The observed angular change will be determined by the star tracker output. Differences between the two define the star tracker accuracy.

The procedures described in the following sections are designed to provide a test accuracy of better than ±0.23s or less than 5 percent of the CID pixel dimension. Further discussion of test errors is presented in Section 5.

Star intensity changes required for Tests 5 and 6 will be accomplished through the use of neutral density filters.

Section 2
TEST EQUIPMENT AND SET-UP

The general test equipment and set up is shown in Figure 2-1. The salient features of the equipment is described below.

2.1 STAR SIMULATOR/AUTOCOLLIMATOR

The star simulator is a compound reflective/refractive system that projects a light source to infinity. The Effective Focal Length (EFL) of the optics is approximately 48 inches.

The source is an illuminated aperture approximately 0.0023 inches (0.00584 cm) in diameter that is illuminated by a trngsten filament lamp.

The angular substense of the projected source is therefore approximately $10\widehat{S}$.

The spectral content of the simulated star will not be defined for this program. However, it will be maintained constant for all tests by operating the lamp at a constant current. Intensity will be varied by introduction of neutral density filters.

The star simulator may also be used as an autocollimator through the use of an eye piece in the optical path. The FOV in the autocollimator mode is $\pm 2.5\widehat{m}$. This feature will be used for alignment of the wedge rotation axis and for coarse alignment of the tracker.

2.2 DEVIATION WEDGE DRIVE ASSEMBLY

The drive assembly contains two independent sets of counter rotating gears. Either set may be independently driven by a DC motor that is coupled to the gears.

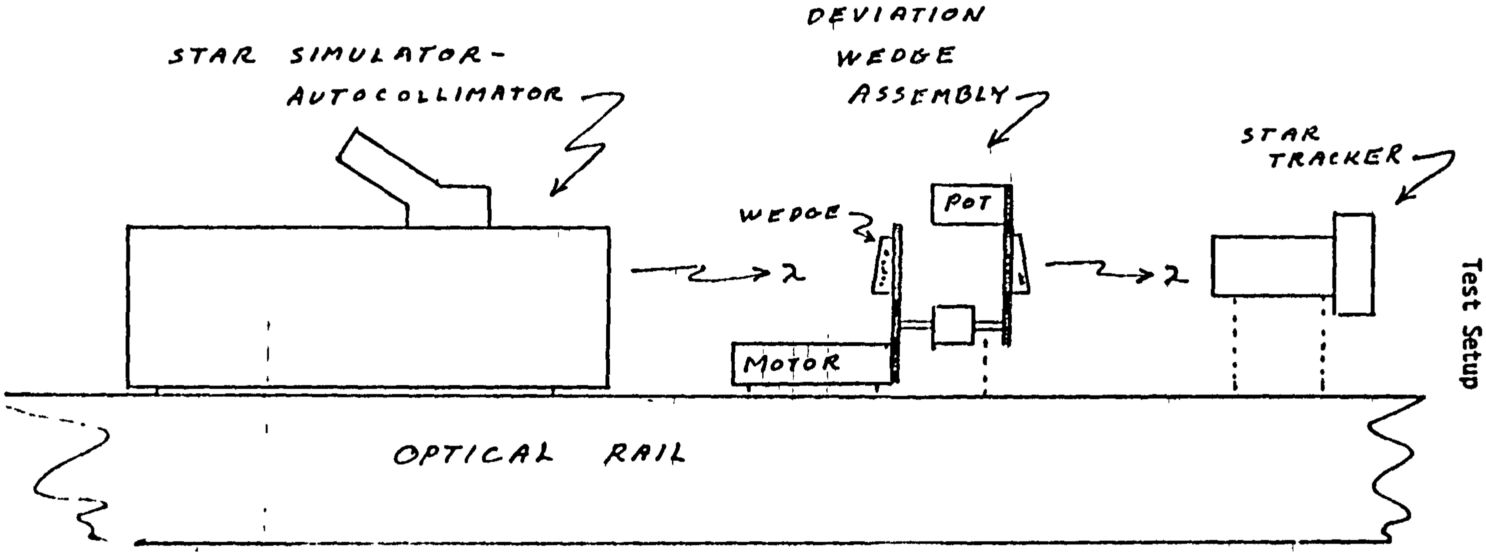


Figure 2-1
Test Setup

Four deviation wedges with adaptors are provided with the assembly. The deviation angle of each is approximately 12m. The wedges may be adapted and oriented in several configurations for varying effects. Some of the alternatives are as follow:

a. Attach a wedge to each of the gears. Each counter rotating set will the yield linear deviation as a function of wedge rotation.

   This configuration can be used to provide independant horizontal (x) and vertical (y) displacement of the star in the focal plane of the tracker.

b. Attach one wedge to one gear so that circular motion is provided in the focal plane.

c. Attach two wedges to one gear and index their deviation vectors to achieve a desired resultant deviation. Rotation now results in circular motion with an adjustable angular diameter. (0 to 24m)

d. Attach two wedges to each gear of one set. Linear, or eliptical, deviation of adjustable amplitude occurs when counter rotated depending on the indexing of each wedge pair.

Each wedge has a scribe line on its edge indicating the direction light will be deviated.

Each wedge housing has 132 teeth on its perifery at intervals of 2.727 degrees. These teeth along with the wedge scribe, will allow for coarse indexing of wedge pairs to achieve a desired resultant deviation.

A lock for the gears farthest from the motor is provided to select the set that is driven. When disengaged that set will drive. When engaged the other set will drive. The two sets are coupled through planetary friction drive gears.

A one percent linear potentiometer is provided with the system and may be coupled to one gear of either counter rotating set. The coupling gear ratio is 1:5 so that the potentiometer rotates five times for one rotation of the gear. Each pot rotation is therefore 72 degrees of gear rotation. This yields an equivalent accuracy in reading gear position of ±0.2 percent or 0.72 degrees, neglecting backlash and tooth variations. The test process defined in paragraph 3 and 4 reduces the effects of this error to less than 0.1S or 0.0025 pixels as seen by the tracker.

2.3 STAR TRACKER

The star tracker lens is a Nikon f/2.0, 50 mm camera lens.

The ST-256 CID is mounted at the focal plane of the lens. The CID is a 256 x 256 pixel detector array with a pixel size of 20 x 20 µm.

The EFL of the lens is 100 mm which results in a pixel angular subtense of approximately 41.253S. The array therefore provides a square field of view of approximately 2.9335 degrees on an edge.

The CID tracker data is acquired and processed through the use of a Comemco Z-80 microprocessor development set.

A basic acquisition and track mode is mechanized so that the FOV is searched until a "star" is found. The "star" is then tested to insure that it is not just a faulty pixel. If it is a faulty pixel, acquisition search is continued. If it is not, it will be tracked until it leaves the FOV or is lost by other means such as too high a rate. When it is lost the acquisition mode is reinitiated.

BASD's tracking algorithm does not require position information so that star position is not computed in the basic track loop. Star position can however be determined from the signals generated while tracking.

This is accomplished by recording the tracking data and computing position after-the-fact.

Critical tracker parameters such as integration time and number of NDRO's are controllable from the terminal. It is also possible to obtain individual pixel data for detailed evaluation of CID defects.

2.4 RAW TEST DATA

The flexibility of the star tracker development equipment allows taking and printing a variety of data.

The minimum raw data that will be furnished for this test is tabulated below. Other data will be furnished as deemed necessary during the test program.

Test Data

a. Test set-up data, hand written (each new set-up). Typical information will include:

- General wedge orientations and configuration
- Star simulator current
- N.D. filters being used
- Star tracker temperature
- Lens f/n
- Test objectives
- Number of NDRO's used
- Integration time
- Update time
- Time and date

b. Tracker data, printed (each data point)

- X-axis output
- Y-axis output

- Star intensity output
- Relative wedge (gear) angle output
- CID temperature

The tracker data will be printed in decimal and will have, attached to it, the related test set-up data.

Data analysis to determine performance will be completed in accordance with instructions described in the procedures of Section 4. All position data will be handled in terms of the pixel linear dimension rather than its angular subtense. Conversion to angular position can be readily made as desired.

Section 3
TEST PROCEDURES

The procedures described in this section describe only the processes required to obtain the desired test data. Parameters such as star intensity or lamp current, CID temperature, lens f/n, number of NDRO's, integration time, updated time, pot voltage, etc. shall be optimized by the operator unless specific requiremnts are called for in the procedures.

This information along with other pertinent information about test conditions shall be recorded on each set of printed data either by writing it on the data sheet or by attaching a separate data sheet.

The procedures herein are established with the intent to minimize test equipment and process errors. Should it become evident that alternate procedures or data would enhance the test program, the procedures will be altered.

All data associated with interpolating position shall be taken with a single compound wedge and the rotation shall be confined to one direction to minimize backlash errors.

3.1 INTER PIXEL TRANSFER FUNCTION, SMALL FIELD POINTING ACCURACY, EFFECTS OF CID PARAMETERS AND RATE TRACKING ACCURACY

The objectives of this test are to:

a. Define the constants required for true position interpolation

b. Evaluate relative accuracy over relatively small areas of the CID (several pixels)

c. Evaluate effects of CID dark current as related to position accuracy

d. Evaluate rate tracking accuracy

The set-up and data taking for these test is combined because similar position data is required to evaluate all associated parameters.

This test evaluates relative performance over several small portions of the total CID FOV, each of which is several pixels in diameter.

3.1.1 Set-up Requirements

a. Assemble two wedges to gear of the front set and the potentiometer and two wedges to one gear of the aft set.

Adjust the front set so that the deviation vectors (scribes) are coincident.

Adjust the aft set so that the deviation vectors (scribes) are separated by approximately 65 teeth on the housings.

Identify the front set as "coarse" and the aft set as "fine."

This configuration will result in a circular scan of the star image for either wedge set when rotated. For the fine set the diameter will be approximately 3.5 pixels and for the coarse, approximately 70 pixels.

b. Adjust the integration time between readings (NDRO's) to zero or the minimum that can be achieved.

c. Adjust the star brightness for the maximum possible while maintaining proper tracking performance.

d. Align the star simulator so the star is near the center of the tracker FOV (typically ±50 pixels)

e. Place a plane parallel mirror against the wedge drive gear and adjust the drive assembly until the return image is in the star simulator/autocollimator FOV.

f. Adjust the CID temperature to approximatley 0°C.

3.1.2 Data Requirements

a. Obtain tracker position wedge angle and intensity data for 60 positions of the fine wedge uniformly spaced at intervals of six degrees wedge rotation. The tolerance for wedge positon settings, as read from the pot, shall be ±2.5 degrees and all settings shall be acquired by rotation in the same direction.

Identify data as "small field pointing, max star, 0°C" (note, if temperature is not 0°C, record actual temperature).

b. Decrease the star intensity by 50 percent and increase the integration time until ouput intensity is the same as that obtained in (a) above. Use approximatley the same wedge rotation angles. Repeat the test of 3.1.2 (a) above and identify data as "small field pointing, 50 percent star, 0°C". (Record integration time.)

c. Decrease the star another 50 percent and increase the integration time for the same intensity read out as above. Identify data as "small field pointing, 25 percent star, 0°C." (Record integration time.)

d. Restablish the conditons of 3.1.2 (a) except for the CIDS temperature.

Repeat the test of 3.1.2 a, b, and c for the CID temperature set at 10°C and then again for the CID temperature set at room temperature.

e. Obtain the pixel outpouts from a 12x12 subarray centered on the locus of positions used for the tests of 3.1.2 a, b, c, and d.

The data shall be taken using the same temperatures and integration times as were used in the above tets for a total of nine sets of data.

f. Repeat the tests of 3.1.2 a, b, c, d, and e at three more positions of the coarse wedge where the positions are set at approximately 90° intervals.

g. Re-establish the conditions of 3.1.2(a) and rotate the fine wedge at a constant rate equivalent to greater than 0.5s/sec deviation. Continuously take data over one complete wedge rotation. Identify the data as rate tracking data. Data shall be reduced and analyzed as described in Paragraph 4.

3.2 LARGE FIELD POINTING ACCURACY AND NOISE EQUIVALENT DISPLACEMENT

The object of this test is to determine the relative pointing accuracy over a larger portion of the CID. The total range tested is approximately 140 pixels in diameter. In addition, the noise equivalent displacement will be measured.

3.2.1 Setup Requirements

Rotate the aft and forward wedges until each pair has maximum deviation as indicated by coincidence of the related wedge scribe marks. Identify the pair coupled to the potentiometer as fine wedge.

Establish the conditions of paragraph 3.1.1 b, c, d, e, and f.

3.2.2 Data Requirements

a. Obtain tracker position, wedge angle, and intensity data for 60 positions of the fine wedge, uniformly spaced at intervals of 6° wedge rotation. THe tolerance for wedge position settings indicated by the pot shall be ±0.5 degrees and all settings shall be acquired by rotation in the same direction. Identify the data as "Large Field Pointing", max star, 0°C.

b. Repeat the test of paragraph 3.2.2 (a) above at three more positions of the coarse wedge where the positions are set at approximately 90° intervals.

c. Remove the coarse wedge and repeat the test of 3.2.2(a).

e. With the CID set at 0°C and the star stationary take at least 50 position readings at each of the following star intensities:

Max Star
80%
50%
32%
10%
3%
1%
0.1%

Identify the data as noise equivalent angle data.

f. Repeat the test of paragraph 3.2.2(e) at reduced NDRO's as follows. Set the integration time for constant intensity readout for each test.

36 NDRO's
16 NDRO's
4 NDRO's
1 NDRO's

Reduce the data in accordance with the procedure of paragraph 4.

3.3 ACQUISITION DYNAMIC RANGE

The purpose of this test is to define the dynamic range for the acquisition loop.

3.3.1 Set-up and Test Requirements

With no star input into the tracker, reduce the acquisition and track threshold until the tracker acquires on dark current noise, then increase the thresholds until it will not remain acquired.

Increase the star intensity until the tracker refuses to acquire, then decrease it so that it just will acquire. Identify the star intensity as "acquisition-max star".

Now decrease the star intensity until it can not be acquired and identify this point as "acqusition min-star".

3.4 OPTIONAL AND EXPLORATORY TESTS

Additional tests may be conducted as deemed necessary by the operator. These tests shall not interrupt the sequential taking of a set of data as defined in previous paragraphs.

When such tests are conducted, the purpose and pertinent information shall be identified on the data sheets.

Section 4
DATA REDUCTION

This paragraph describes the basic reduction processes. Alternate methods that may yield more accurate results may be used at the discretion of the personnel involved.

4.1 INTERPIXEL TRANSFER FUNCTION

A straight line transfer function (outpt vs. displacement) is assumed over each half pixel of displacement. This section defines the constant that must be applied to normalize the output to the pixel dimension.

The four "circles" of data taken under paragraph 3.1.2(a) (Max star, 0°C) shall be used to define the inter-pixel transfer function.

a. Deviation Wedge Zero Position

Review each set of data and identify the two wedge angles at which the tracker x-axis output is a minimum and maximum.

Divide the difference of these angles by two and identify the result as the x-axis zero wedge position. This is the best estimate of zero deviation along the x-axis.

Repeat the process for the y-axis output data and identify the results as y-axis wedge zero.

b. Transfer Function

Using the zero reference position defined in (a) above tabulate x-axis outpt vs cos ϕ_x and y-axis output vs cos ϕ_y. ϕ is the related wedge rotation angle form the zero reference.

The data cycles through zero, in half pixel increments. Obtain a best fit to a straight line for each cycle as illustrated below. Identify the integer pixel cycle as x and the half pixel cycle as x' as shown.

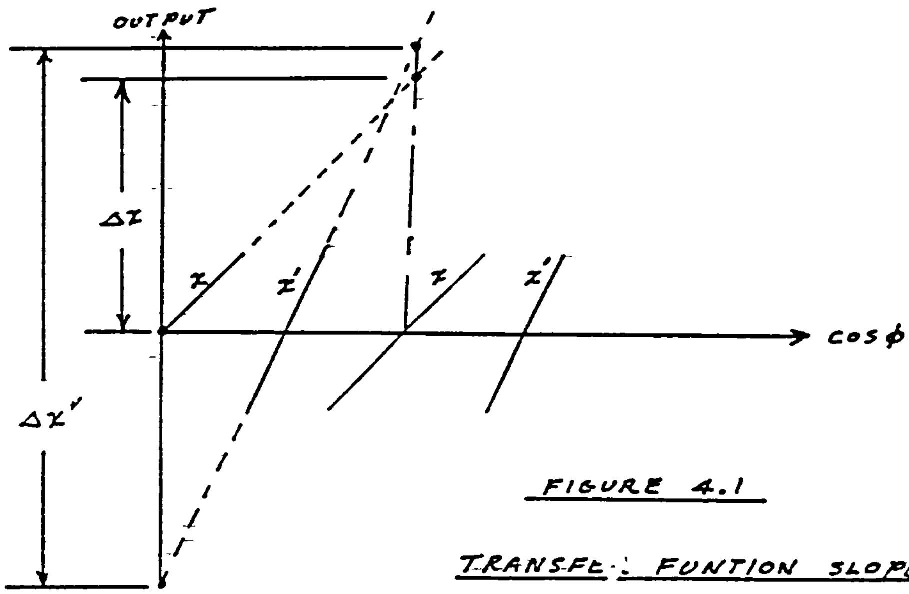


FIGURE 4.1

TRANSFER FUNTION SLOPE

Extend the lines until they overlap two zero crossings and determine the equivalent differential output for these crossing points. Identify them as Δx and $\Delta x'$ respectively for the appropriate cycles as shown. Reduce all cycles available from each set of data to this form and obtain the mean $\overline{\Delta x}$ and $\overline{\Delta x'}$.

The constants for inter-pixel interpretation are determined as follows.

$$K_x = \frac{1}{\overline{\Delta x}} \text{ (integer pixel cycle)}$$

$$K_{x'} = \frac{1}{\overline{\Delta x'}} \text{ (half pixel cycle)}$$

Repeat this process for y axis output data to obtain K_y and K_y'.

Multiplying the related output data by these constants will give x and y position in terms of pixels.

The data obtained in this test shall also be reviewed for systematic non-linearities and compared with the previous analytic results that were obtained.

Several iterations and alternate analytic methods may be used to optimize the constants.

4.2 SMALL AND LARGE FIELD POINTING ACCURACY, CID EFFECTS AND RATE TRACKING ACCURACY

a. Multiply the fractional position data of paragraphs 3.1 and 3.2 by the appropriate constants developed under paragraph 4.1. This normalizes fractional position to the pixel dimensions. Perform the following analysis on all sets of data taken in paragraph 3.1 and 3.2 except for that of 3.2.2(e).

b. For each circular set of data above, review the wedge angle at which the data was taken and identify pairs of data points that are diametrically opposed (approximately 180 deg apart).

$$(x_1, y_1)\ (x_1', y_1') \ldots (x_n, y_n)\ (x_n', y_n')$$

c. Compute, for n=1, 2, 3.....n

$$R_n = [(x_n - x_n')^2 + (y_n - y_n')^2]^{1/2} \div 2$$

where R_n is the deviation of the wedge as measured by the tracker.

Determine the mean $(\overline{R})$ and standard deviation.

d. Determine the best center for each circle of data points and identify it as (x_c, y_c).

Compute:

$$R_{nc} = [(x_c - x_n)^2 + (y_c - y_n)^2]^{1/2}$$

for n = 1, 2, 3....n

Determine the mean $(\bar{R}_{nc})$ and standard deviation.

4.3 NOISE EQUIVALENT DISPLACEMENT (NED)

Determine the mean and standard deviation for the data taken under paragraph 3.2.2(e).

4.4 ADDITIONAL ANALYSIS

Additional analyses and alternate approaches may be accomplished as deemed necessary or desirable. However, the analyst is cautioned that alternate approaches may result in introduction of larger test equipment errors.

The greatest contribution to uncertainty is assumed to result from the one percent potentiometer. The procedures outlined above are designed to limit the resultant contribution to ±0.2S in data uncertainty.

Section 5
RELATED EQUATIONS, ANALYSES, AND ERRORS

This paragraph presents pertinent information associated with the test process and data reduction.

5.1 DEVIATION WEDGE AND ASSOCIATED ERRORS

5.1.1 Deviation Angle

Figure 5-1 illustrates the geometry involved where:

- A = apex angle of the compouond-wedge
- N = Normal to wedge-entrance surface
- i = the incident angle of ref. axis (input light axis) relative to N
- r = refractive angle relative to N
- N' = normal to wedge exit surface
- r' = refractive angle relative to N'
- i' = angle of exit light axis relative to N'
- D = angle of exit light axis relative to input axis (deviation angle)
- μ = refractive index of glass

The basic expression for refraction is:

$$\mu = \frac{\sin i}{\sin r} \qquad (5\text{-}1)$$

and by similarity

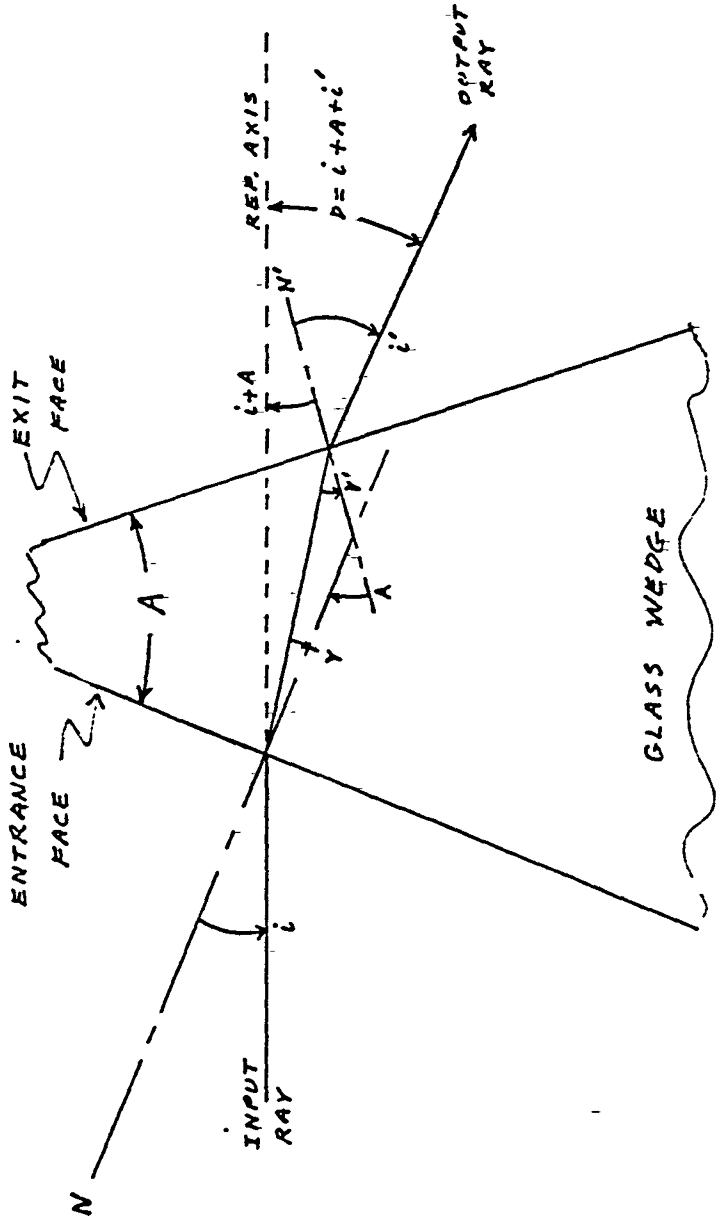
$$\mu = \frac{\sin i'}{\sin r'} \qquad (5\text{-}2)$$

from Figure 5.1 it is seen that

$$r' = -(\gamma + A) \qquad (5\text{-}3)$$

$$D = i + A + i' \qquad (5\text{-}4)$$

Figure 5-1
Deviation Wedge Geometry



By substitution of equation 5-1 through 5-4 we get

$$D = i + A - \sin^{-1}[\mu \sin [\sin^{-1} (\frac{\sin i}{\mu}) + A]] \qquad (5\text{-}5)$$

The signs for the terms in equations 5-3, 5-4 and 5-5 are selected for proper polarity for the conditions of Figure 5-1. If the wedge were inverted, such as in our rotating application, the signs of values for (i) and (A) of equation 5-5 would also change.

5.1.2 Error or Uncertainty in Deviation Angle

From Figure 5-1 it is seen that the magnitude of (i) will not change if the wedge is rotated about the reference axis. By similarity, it will not change if the wedge is rotated about the normal to the entrance surface (N).

If we define the angle between rotation axis and reference axis as (B) the angles between the entrance face, (N) and the rotation axis as (α), it is seen that for the first example (i) would be equal to (α) and for the second example (i) would equal (B).

Therefore, the resultant deviation magnitude (D) would be constant for full rotation of the wedge, which is the desired condition for this application.

These, however, are unique conditions where the two angles did not exist simultaneously.

If the two angles do exist simultaneously, the magnitude of deviation will vary as the wedge is rotated. The value of (i) will tend to have a mean value of (α) and will vary from (α + B) to (α - B). The measured deviation (D_m), will then become

$$D_m = D \pm \Delta D \qquad (5\text{-}6)$$

Where (D) in this case is the mean deviation defined by eg., 5-5, and (ΔD) the error from misalignment.

It is evident that the effects of (α) and (B) can be included in the overall expression for (D_m) if their magnitude and direction are known. This however would greatly complicate the data handling and evaluation process.

A simpler approach is to limit the magnitude of (α) and (B) so that the residual error (ΔD) can be tolerated as an uncertainty in the true deviation.

The expression for (ΔD) is found by substituting (α+B) for (i) equation 5-5 then finding the difference in results for B=0 and B=maximum. Therefore,

$$\Delta D = \sin^{-1}[\mu \sin [\sin^{-1} (\frac{\sin \alpha+B}{\mu}) + A]] - \sin^{-1} [\mu \sin [\sin^{-1} (\frac{\sin \alpha}{\mu}) + A]] - B \quad (5\text{-}7)$$

which describes the maximum variation from constant deviation as the wedge is rotated.

5.1.3 Error Budget

In our application we are attempting to verify performance of approximately 0.4S. We will therefore arbitrarily set $\Delta D < 0.1S$.

The wedge used for the test consists of two 23m wedges each of which is an achromatic, crown/flint glass combination having an index of refraction of approximately $\mu = 1.53$.

The wedges are rotated relative to each other to provide a fixed apex angle that is adjustable from zero to 46m. Since the worse error occurs at maximum apex angle we will set A = 46m.

The wedges are mounted so that the normal to the entrance surface is typically misaligned from the rotating axis by 23m to allow for some assembly tolerance we will set α = 30m.

Substituting these values for ΔD, μ, A and α into equation 5-7 and iterating to a solution we get,

$$B < 6m$$

for

$$\Delta D < 0.1S$$

The wedge rotation axis must therefore be aligned to the reference axis, which in this case will be the star simulator axis, to better than 6m to maintain the deviation uncertainty within 0.1S.

As the compound wedge an (A) is decreased the tolerance on B increases somewhat proportionally.

Table 5-1 gives the relationship of B_{max} vs. A for ΔD < 0.1s and α < 30m. The approximate mean wedge devition (D) is also tabulated.

Table 5-1
WEDGE ROTATION AXIS ALIGNMENT REQUIREMENTS (B)
vs.
COMPOUND WEDGE APEX ANGLE (A) AND DEVIATION ANGLE (D)

A	D	B_{max}
46 m	1463 s	6 m
40 m	1272 s	7 m
30 m	954 s	11 m
20 m	636 s	17 m
10 m	318 s	31 m
5 m	159 s	51 m
2 m	63 s	89 m
1 m	31 s	132 m

Use of the auto collimator feature of the star simulator will result in B< 2.5m insuring an uncertainty of less than 0.1s.

5.2 DATA TAKING AND REDUCTION

5.2.1 Wedge Angle Setting Tolerance

The test process of paragraph 3 requires taking data at specific positions of 0 wedge rotation. The process results in a locus of input positions that lie on a true circle within ±0.1 s (±.0025 pixels) as discussed in paragraph 5.1.

The radius of the circle (R_n) seen by the tracker, is found by resolving the cord length between diametrically opposed data points as described in paragraph 4.2(b) and (c). Since there is an uncertainty in the relative angle between data points due to pot readout uncertainty, a potential source of error exists.

Assume the data points are taken 180 $\pm\Delta\phi$ degrees apart, where $\Delta\phi$ is the uncertainty in wedge angle between points. The measured half cord length (R_n) between data points is then:

$$R_n = D \sin \frac{180 + \Delta\phi}{2} \qquad \text{eq. 5.8}$$

where (D) is the deviation angle of the wedge. The error resulting from assuming the points are exactly 180 degrees apart is therefore:

$$\Delta Rn = D(1- \sin \frac{180 + \Delta\phi}{2}) \qquad \text{eq. 5.9}$$

If we wish to set a limit on $\Delta\phi$ to achieve a given $\Delta Rn(max)$, we get:

$$|\Delta\phi_{max}| < 2 \sin^{-1}(1- \frac{\Delta Rn(max)}{D})-180 \qquad \text{ea. 5.10}$$

For our application, we will limit the error to 0.1s, therefore $\Delta Rn(max)=0.1s$. Our tests use two deviation angles. For the small field, D<200s and for the large D~1463s.

Substituting into eq. 5.10, we get:

Small field $\Delta\phi_{max} < 3.62$ degrees

and

Large field $\Delta\phi_{max}$ 1.34 degrees

Since the readout accuracy of the pot is approximately ± 0.8 degrees, the wedge rotation positions must be set to accuracies of ± 2.6 degrees and ± 0.5 degrees respectively for the small and large field pointing tests of 3.1 and 3.2

5.3 INTENSITY AND DARK CURRENT MEASUREMENTS

The CID will be used for all intensity and dark current measurements. If signals are converted to equivalent electrons, the dark current (I_d) and star magnitude are found by:

$$I_d = \frac{4s}{N(Tr + 2Ti)} \frac{e^-}{sec}$$

and

$$M_v = \log_{2.51} \frac{4.465 \times 10^7 \, N(T_r + 2T_i)}{S \, (f/n)^2}$$

Where:

I_d ≡ dark current e/sec

S ≡ signal e

N ≡ Total number of readings in 1st and 2nd set of reads

T_r ≡ Time spend taking 1st and 2nd set of reads

T_i ≡ Integration time between 1st and 2nd set of reads

M_v ≡ Star Magnitude

f/n ≡ lens f number setting

Note that signal from all pixels containing the star must be used for m_v computation.

If the digital signal (S_d) is not converted to electrons, using our scaling of 179.5 e per LSB we get:

$$M_v = \log_{2.51} \frac{2.488 \times 10^5 \, N(T_r + 2\,T_i)}{S_d (f/n)^2}$$

Where S_d is now the decimal equivalent of the signal directly from the tracker.

5.3.1 Signal Formula

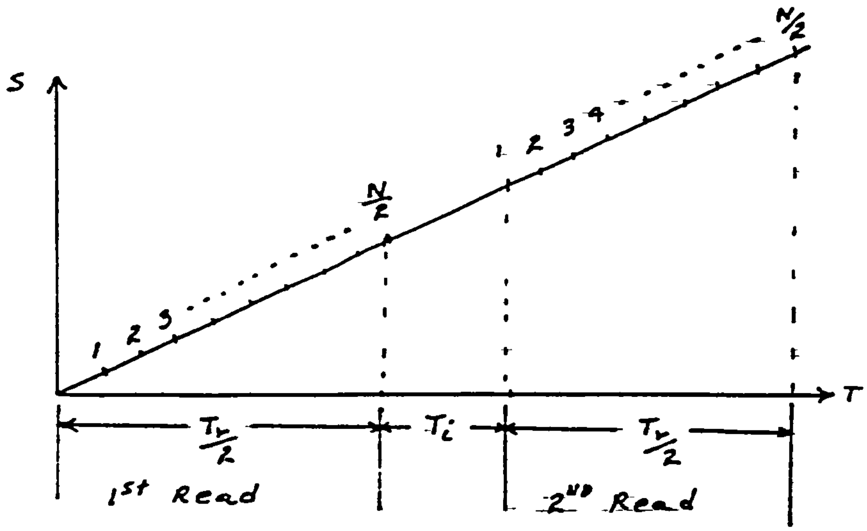
The basic equation for signal output is:

$$s = 0.25 E_s N(T_r + 2T_i)$$

where:

s ≡ output signal in electrons (e)
E_s ≡ electron generation rate (e/sec)
N ≡ Total number of NDRO's in first and second read
T_r ≡ total time spent taking the first and second read
T_i ≡ Integration time between the first and second read

Figure 5.2 illustrates the parameters



Since the observed signal may be dark current (I_d) or signal current (I_s), we can use this basic equation for either measurement. By substitution we get:

$$I_d = \frac{4S}{N(T_r + 2T_i)} \quad \frac{e^-}{sec}$$

and

$$I_s = \frac{4S}{N(T_r + 2T_i)} - I_d \quad \frac{e^-}{sec}$$

Our process internally subtracts (I_d) when tracking a star, so that:

$$I_s = \frac{4S}{N(T_r + 2T_i)}$$

When computing I_s, the signal(s) from all pixels containing the source must be used.

5.3.2 Star Magnitude Formula

The signal formula can be used to compute star magnitude by introducing the lens parameters, CID response and star spectral distribution.

Integration of a GO V, zero magnitude star over GE's published response for the CID results in a current of:

$$(OM_v)\ I_s = 2.8427 \times 10^6 \frac{e^-/sec}{cm^2} A$$

Where (A) is the combined lens efficiency and area. Assuming an efficiency of 0.8, the signal for a given M_v star is:

$$I_s = \frac{2.8427 \times 10^6}{2.51^{M_v}} \times 0.8 \pi r^2$$

where (r) is the lens radius and,

$$r = \frac{EFL}{2\ f/n}$$

Therefore,

$$I_s = \frac{1.786 \times 10^6}{2.51^{M_v}} \left(\frac{EFL}{f/n}\right)^2$$

and by substitution,

$$\frac{4S}{N(T_r + 2T_i)} = \frac{1.786 \times 10^6}{2.51^{M_v}} \left(\frac{EFL}{f/n}\right)^2$$

$$2.51^{M_V} = \frac{4.465 \times 10^5 \, N(T_r + 2T_i)}{S} \left(\frac{EFL}{f/n}\right)^2$$

or

$$M_V = \log_{2.51} \frac{4.465 \times 10^5 \, N(T_r + 2T_i)}{S} \left(\frac{EFL}{f/n}\right)^2$$

5.3.3 Breadboard Formula

Since our Breadboard lens has an EFL of 10 cm and a variable f/n:

$$M_V = \log_{2.51} \frac{4.465 \times 10^7 \, N(T_r + 2T_i)}{S \, (f/n)^2}$$

Our signal is scaled for 179.5e⁻ per LSB so that if the digital signal (S_d) is not converted to electrons.

$$M_V = \log_{2.51} \frac{2.488 \times 10^5 \, N(T_r + 2T_i)}{S_d \, (f/n)^2}$$

TR81-04

REPORT APPENDIX B

FITTING DATA TO THE EQUATION OF A CIRCLE BY THE METHOD OF LEAST SQUARES

REPORT NO. SER 86200011

JUNE 8, 1981

FITTING DATA TO THE EQUATION OF A CIRCLE BY THE METHOD OF LEAST SQUARES

A method of fitting data to the equation of a circle by the method of least squares is developed. The method is analogous to a linear least squares fit but is valid for circles and can be extended with appropriate caution to any conic section.

The Problem

The currently planned method for generating well known star position changes for testing of the CID tracker system is to rotate glass wedges in the star collimator optical path. This rotation will produce a circular path for the focal plane star image. This nonlinear path presents a problem in data reduction.

The most convient method of fitting the tracker output data to the star position has always been to perform a least square fit of the data to a linear scan of the star across the array. A circular star path requires fitting tracker data to a circle, and we were unable to find an expression for this in the literature.

The Approach

The method of least squares requires that the sum of the square of the residuals, v_i, in the following expression be minimized.

$$v_i = \bar{y}_i - y_i$$

where $\bar{y}_i$ is the value of y obtained by substituting $x_i = x$ into the equation $y = f(x)$.

If the equation is of the form:

$$f(x, y) = 0$$

$$v_i = f(x_i, y_i)$$

If we define this sum as S we may say:

$$S \equiv \sum_{i=1}^{n} v_i^2$$

The expression, f (x), will have unknowns; a_1 a_2, a_k which are to be evaluated with the n, (x_i, y_i) data sets. The necessary and sufficient condition which minimizes S is that:

$$\frac{\delta S}{\delta a_1} = 0, \frac{\delta S}{\delta a_2} = 0, \ldots \frac{\delta S}{\delta a_k} = 0.$$

A circle can be expressed as a polynominal in two variables, f (x, y) = 0.

$$(x - x_0)^2 + (y - y_0)^2 - R^2 = 0$$

or

$$x^2 + y^2 - 2 x_0 x - 2 y_0 y + x_0^2 + y_0^2 - R^2 = 0$$

We know that the only unknowns are x_0 and y_0, the location of the center of the circle and R, its radius. We will set:

$$a_0 = -2x_0 \qquad a_1 = -2y_0$$

and

$$a_2 = x_0^2 + y_0^2 - R^2$$

It is at this point that our analysis ceases to be entirely rigoris. The partial differential equations:

$$\frac{\delta S}{\delta a_k} = 0$$

are required to be independant of one another, and it is clear that in this construction $a2$ is a function of $a1$ and a_0.

We can extract ourselves from this dilema if we have an approximate knowledge of the location of the center of the circle. If this approximate value is subtracted from the data such that $a_2 = -R^2$ the independance of the partial differential expressions is preserved and we may proceed with our development.

Using the substution above our expression for a circle becomes:

$$x2 + y^2 + a0\ x + a1\ y + a2 = 0$$

Remembering that:

$$v_i = f(xi,\ yi)$$

we have:

$$S \equiv \sum_{i=1}^{n} v_i^2 = \sum_{i=1}^{n} f(x_i,\ y_i)^2$$

and

$$\frac{\delta S}{\delta a_0} = \sum_{i=1}^{n} 2\ x_i\ (x_i^2 + y_i^2 + a_0\ x_i + a_1\ y_i + a_2) = 0$$

$$\frac{\delta S}{\delta a_1} = \sum_{i=1}^{n} 2\ y_i (x_i^2 + y_i^2 + a_0\ x_i + a_1\ y_i + a_2) = 0$$

$$\frac{\delta S}{\delta a_2} = \sum_{i=1}^{n} 2\ (x_i^2 + y_i^2 + a_0\ x_i + a_1\ y_i + a_2) = 0$$

abbreviating $\sum_{i=1}^{n}$ to Σ, and dividing all three equations by two we obtain:

$$\Sigma x_i^3 + \Sigma x_i y_i^2 + a_0 \Sigma x_i^2 + a_1 \Sigma x_i y_i + a_2 \Sigma x_i = 0$$

$$\Sigma x_i^2 y_i + \Sigma y_i^3 + a_0 \Sigma x_i y_i + a_1 \Sigma y_i^2 + a_2 \Sigma y_i = 0$$

$$\Sigma x_i^2 + \Sigma y_i^2 + a_0 \Sigma x_i + a_1 \Sigma y_i + a_2 n = 0$$

In matrix form this may be expressed as:

$$\begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} \times \begin{bmatrix} \Sigma x_i^2 & + \Sigma x_i y_i & + \Sigma x_i \\ \Sigma x_i y_i & + \Sigma y_i^2 & + \Sigma y_i \\ \Sigma x_i & + \Sigma y_i & + n \end{bmatrix} = \begin{bmatrix} -\Sigma x_i^3 - \Sigma x_i y_i^2 \\ -\Sigma x_i^2 y_i - \Sigma y_i^3 \\ -\Sigma x_i^2 - \Sigma y_i^2 \end{bmatrix}$$

After solution of this expression for a_0, a_1, and a_2:

$$x_0 = -\frac{a_0}{2}$$

$$y_0 = -\frac{a_1}{2}$$

and

$$R^2 = \frac{a_0^2}{4} + \frac{a_1^2}{4} - a_2$$

The residuals are evalulated by substituting the input data pairs into the original expression after the a_k have been evaluated.

$$v_i = x_i^2 + y_i^2 + a_0 x_i + a_1 y_i + a_2$$

As in a linear least squares analysis, the standard deviation of the v_i is the most reasonable measure of the quality of the fit.

Applicability

It should be noted that this method is useful for any two dimensional expression in which the power of the variables take on positive integer values as long as the data can be manipulated to maintain independence of the partial differential equations.

The general expression for a conic section is clearly applicable:

$$b_0 x^2 + b_1 y^2 + b_2 x + b_3 y + b_4 = 0$$

SOURCE

1. Sokolnikoff, I.S. and E.S. Higher Mathematics for Engineers and Physicists, McGraw-Hill, 1941, Page 536.

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MAR. 26, 1982

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